TECHNICAL REPORT
NATICK/TR-81/031

EFFECTS OF EXPLOSIVE ORDNANCE DISPOSAL (EOD) ARMOR ON THE GROSS BODY MOBILITY, PSYCHOMOTOR PERFORMANCE, SPEECH INTELLIGIBILITY, AND VISUAL FIELD OF MEN AND WOMEN

by
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May 1981

UNITED STATES ARMY
NATICK RESEARCH and DEVELOPMENT LABORATORIES
NATICK, MASSACHUSETTS 01760

Clothing, Equipment & Materials Engineering Laboratory

CEMEL-235

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: NATICK/TR–81/031
2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle): EFFECTS OF EXPLOSIVE ORDNANCE DISPOSAL (EOD) ARMOR ON THE GROSS BODY MOBILITY, PSYCHOMOTOR PERFORMANCE, SPEECH INTELLIGIBILITY, AND VISUAL FIELD OF MEN AND WOMEN
5. TYPE OF REPORT & PERIOD COVERED
6. PERFORMING ORG. REPORT NUMBER: CEMEL–235

7. AUTHOR(s): Richard F. Johnson, Ph.D.
8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS: Clothing, Equipment and Materials Engineering Lab, US Army Natick R&D Laboratories, Natick, MA 01760
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 1G464713DL40282

11. CONTROLLING OFFICE NAME AND ADDRESS: US Army Natick R&D Laboratories, Natick, MA 01760, ATTN: DRDNA–VCCH
12. REPORT DATE: May 1981
13. NUMBER OF PAGES: 194

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
15. SECURITY CLASS. (of this report): UNCLASSIFIED
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

PROTECTIVE CLOTHING	PSYCHOMOTOR FUNCTION	SPEECH
OVERGARMENT	BOMBS	VISION
BODY ARMOR	ORDNANCE	BODY MOBILITY
EXPLOSIVE ORDNANCE DISPOSAL	MALES	
UNEXPLODED AMMUNITION	FEMALES	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Four commercially-available explosive ordnance disposal (EOD) suits were evaluated in order to determine their effects on the wearer's gross body mobility, psychomotor performance, speech intelligibility, and visual field. Six Army enlisted men and six Army enlisted women were tested under six conditions: (1) fatigues and combat boots, (2) fatigues and combat boots with infantry armor vest and helmet, (3) Commercial A EOD armor, (4) Commercial B EOD armor, (5) Commercial C EOD armor, and (6) Commercial D EOD armor. Although

20. ABSTRACT (Continued)

different in design, each EOD suit consisted of a helmet, faceshield, torso armor, and upper and lower extremity armor. Commercial A and B EOD armor provided better mobility, psychomotor performance, speech intelligibility and field of vision than did Commercial C and D EOD armor. All four EOD suits were equivalent in terms of the wearer's ability to hear human speech accurately. Overall, test subject performance was best in Commercial A EOD armor and poorest in Commercial D EOD armor. There were no important differences between men and women in terms of ability to operate within the EOD suits.

PREFACE

The study reported here was conducted by members of the Human Factors Group; Clothing, Equipment, and Materials Engineering Laboratory. The author wishes to express his appreciation to SP5 Stanley M. Walker for his assistance during the collection and analysis of the data, and to the 14th Ordnance Detachment (EOD), Fort Devens for their suggestions and comments during the planning of the study.

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INTRODUCTION

The role of US Army explosive ordnance disposal (EOD) personnel is to locate, identify, render safe, remove and destroy explosive ordnance. Men and women are permitted to volunteer for EOD duty. These personnel have no protection from high speed fragments commonly associated with unexploded ordnance (UXO) and improvised explosive devices (IED). However, a formal Letter Requirement now exists for body armor for EOD personnel engaged in operations involving small UXO and IED (see Appendix A).[1] As part of its role in this program, the US Army Natick Research and Development Laboratories (NLABS) procured four commercial EOD suits of armor for evaluation with respect to certain major performance characteristics. The performance characteristics which are the object of this report include the following:

a. the extent to which EOD armor may impair the gross body mobility of the wearer (para. 5a(3) and 5a(16));

b. the extent to which EOD armor may impair the psychomotor, or eye-hand, coordination of the wearer (para. 5a(3) and 5a(14));

c. the extent to which EOD armor may impair the ability of the wearer to hear speech (para. 5a(4));

d. the extent to which EOD armor may impair the ability of the wearer to be heard when speaking (para. 5a(16));

e. the extent to which EOD armor may impair the visual field of the wearer (para. 5a(4)); and

f. the speed with which EOD armor may be donned and doffed (para. 5a(15)).

The study reported here evaluated the influence of EOD armor on the performance of both men and women.

[1] Letter Requirement (LR) for body armor for explosive ordnance disposal (EOD) units (ACN 21203). Fort Monroe, Virginia: HQ, US Army Training and Doctrine Command, 6 February 1978.

Overview of the Evaluation

Six men and six women donned each of four commercial EOD suits of armor and were administered a series of tests while wearing each suit. These tests included (a) a gross body mobility investigation, (b) a psychomotor performance investigation, (c) a speech intelligibility investigation, and (d) a visual field investigation. Administration of these tests required eight days of participation by each subject. Days 1 and 2 were set aside for the investigation of gross body mobility. Days 3 through 6 were set aside for the investigation of psychomotor performance and the hearing portion of the speech intelligibility investigation. Day 7 was set aside for the visual field investigation. Day 8 was set aside for the speech communication portion of the speech intelligibility investigation. The men's and women's subjective impressions of the suits were solicited by means of formal questionnaires which were administered throughout the eight days of testing.

Since there is no standard Army EOD armor against which to compare the performance of the four commercial EOD suits, two control conditions were included: a **no armor condition** in which the test subject wore only standard fatigues and combat boots, and an **infantry armor condition** in which the subject wore standard fatigues, combat boots, Personnel Armor System for Ground Troops (PASGT) armor vest, PASGT helmet, and combat vehicle crewman's (CVC) goggles. The no armor condition represents the real-life condition of EOD personnel as they operate today, while the infantry armor condition represents a potential armor ensemble EOD personnel could wear if they utilized current US Army stock armor items.

Test Subjects

Twelve test subjects, six men and six women, were recruited from the NLABS Enlisted Volunteer Platoon. None had EOD experience. Prior to volunteering for this particular study, the subjects were informed of the purpose of the study and the specific tasks they would be asked to perform. All subjects were between 19 and 23 years of age. Selected body dimensions of the subjects are presented in Table 1.

EOD Armor Conditions

Each of the 12 subjects was administered all tests under each of six body armor conditions.

1. **No Armor.** This condition consisted of fatigue shirt, fatigue trousers, and combat boots. Photographs of this condition are presented in Figures 1 and 2 for men and Figures 3 and 4 for women.

2. **Infantry Armor.** This condition consisted of the same clothing as the No Armor condition with the addition of the PASGT armor vest, the PASGT helmet, and the CVC goggles. The size PASGT vest each subject wore in this condition is presented in Table 1. The weights of the suit components are presented in Table 2. Photographs of the Infantry Armor condition are presented in Figures 5 and 6 for men and Figures 7 and 8 for women.

Table 1

Body Dimensions of Test Subjects

Subject No.	Stature (cm)	Weight (kg)	Chest/Bust Circumf. (cm)	Waist Circumf. (cm)	Size Armor Vest Worn		
					Infantry	A	B
Men							
1	177	71.3	104	81	M	M	M
2	175	74.6	99	94	M	L	L
3	188	61.4	86	76	S	M	M
4	178	72.0	97	81	M	M	M
5	173	70.5	103	84	M	M	M
6	188	90.1	112	91	L	L	L
Mean	179.8	73.3	100.2	84.5			
Women							
7	157	59.1	97	76	M	S	S
8	160	56.1	89	74	S	S	S
9	167	58.2	89	79	S	S	S
10	171	58.6	85	72	S	S	S
11	159	63.8	94	73	S	S	S
12	164	59.9	93	70	M	M	M
Mean	163.0	59.3	91.2	74.0			
All Subjects							
Mean	171.4	66.3	95.7	79.3			

NOTES: Stature was measured in stocking feet.
Weight does not include clothing.
Circumferences were measured over the subject's fatigues.
The infantry armor vest was fitted loosely enough so that the vest would easily rise on the body during abduction of the upper arms. Commercial A and B vests were fitted to provide the most area coverage without the breast plate extending beyond the torso.

Table 2

Component Weights (kg.) of EOD Suits Tested

Suit Component	Size small	medium	large
Infantry Armor			
helmet, PASGT	1.43	1.46	1.54
vest, PASGT	3.76	4.20	4.59
goggles, CVC	0.12	0.12	0.12
Total Suit Weight:	5.31 (11.68 lbs.)	5.78 (12.72 lbs.)	6.25 (13.75 lbs.)
Commercial A Armor			
helmet w/faceshield	3.92	3.92	3.92
vest (chest + back plates w/cover)	5.73	6.89	8.08
leggings	3.52	3.52	3.52
sleeves	2.95	2.95	2.95
Total Suit Weight:	16.12 (35.46 lbs.)	17.28 (38.02 lbs.)	18.47 (40.63 lbs.)
Commercial B Armor			
helmet w/faceshield	4.24	4.24	4.24
vest (chest + back plates w/cover)	7.99	9.63	11.56
leggings	2.59	2.59	2.59
sleeves w/collar + bib	3.48	3.48	3.48
Total Suit Weight:	18.30 (40.26 lbs.)	19.94 (43.87 lbs.)	21.87 (48.11 lbs.)
Commercial C Armor			
helmet w/faceshield			4.76
chest plate			3.29
pelvic plate			1.57
front apron w/ collar + sleeves			7.05
back apron			3.53
leggings			3.62
Total Suit Weight:			23.82 (52.40 lbs.)
Commercial D Armor			
helmet w/faceshield			4.76
chest plate			4.05
pelvic plate w/cover			1.86
apron w/sleeves			11.22
collar			1.61
attenuation vest			1.50
gaiters			2.36
Total Suit Weight:			27.36 (60.19 lbs.)

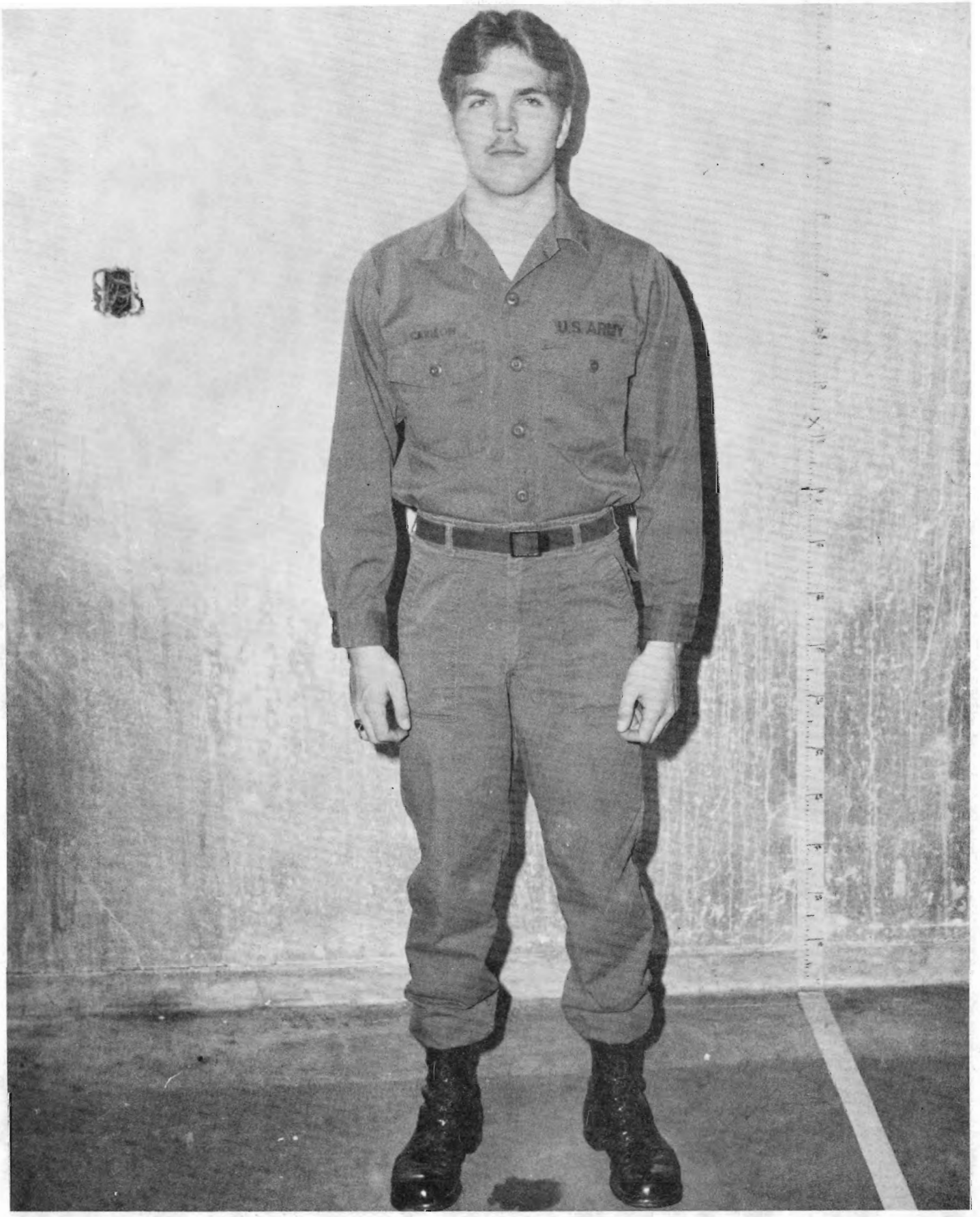

Figure 1. Front view of male subject in No Armor condition.

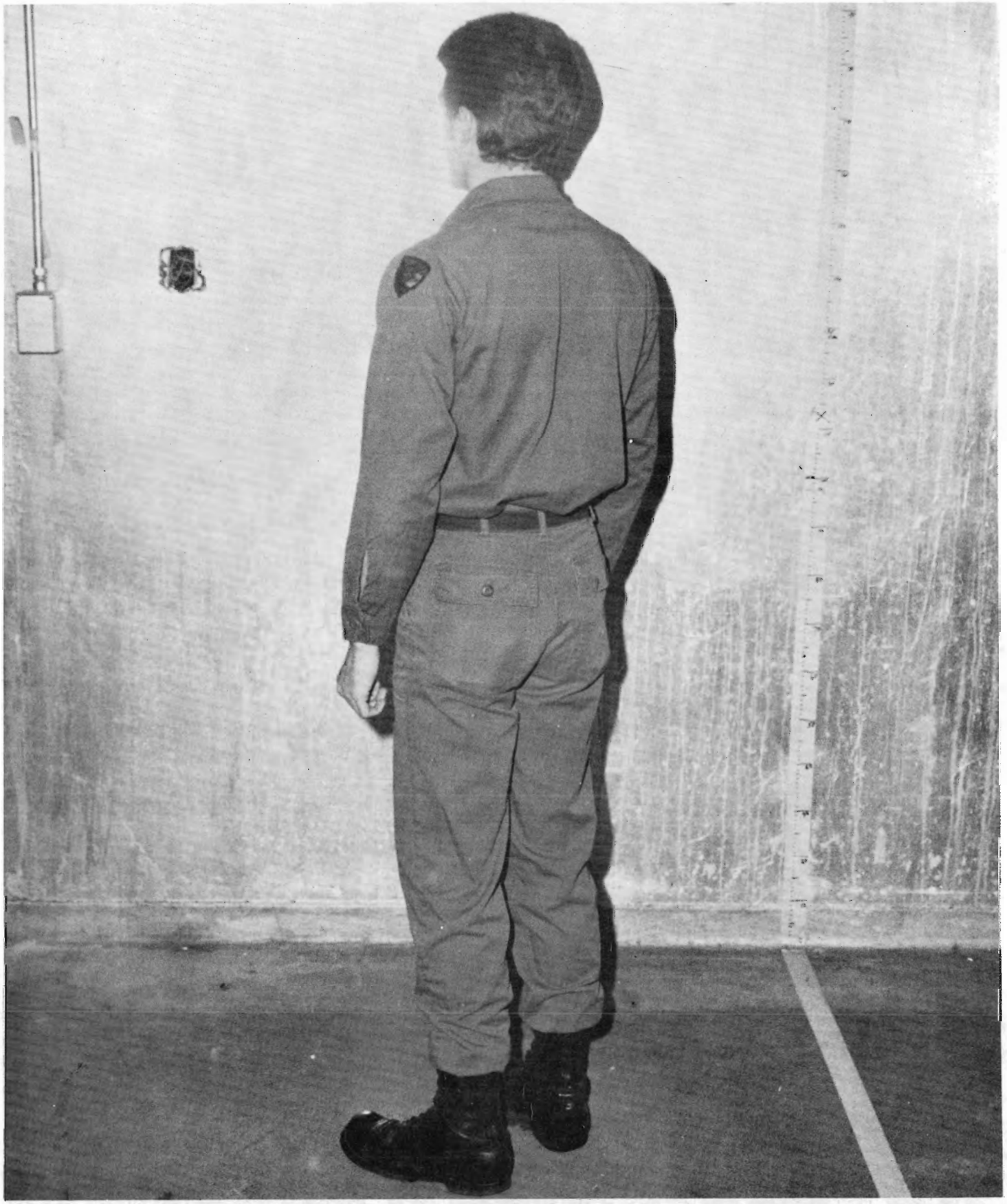

Figure 2. Back view of male subject in No Armor condition.

Figure 3. Front view of female subject in No Armor condition.

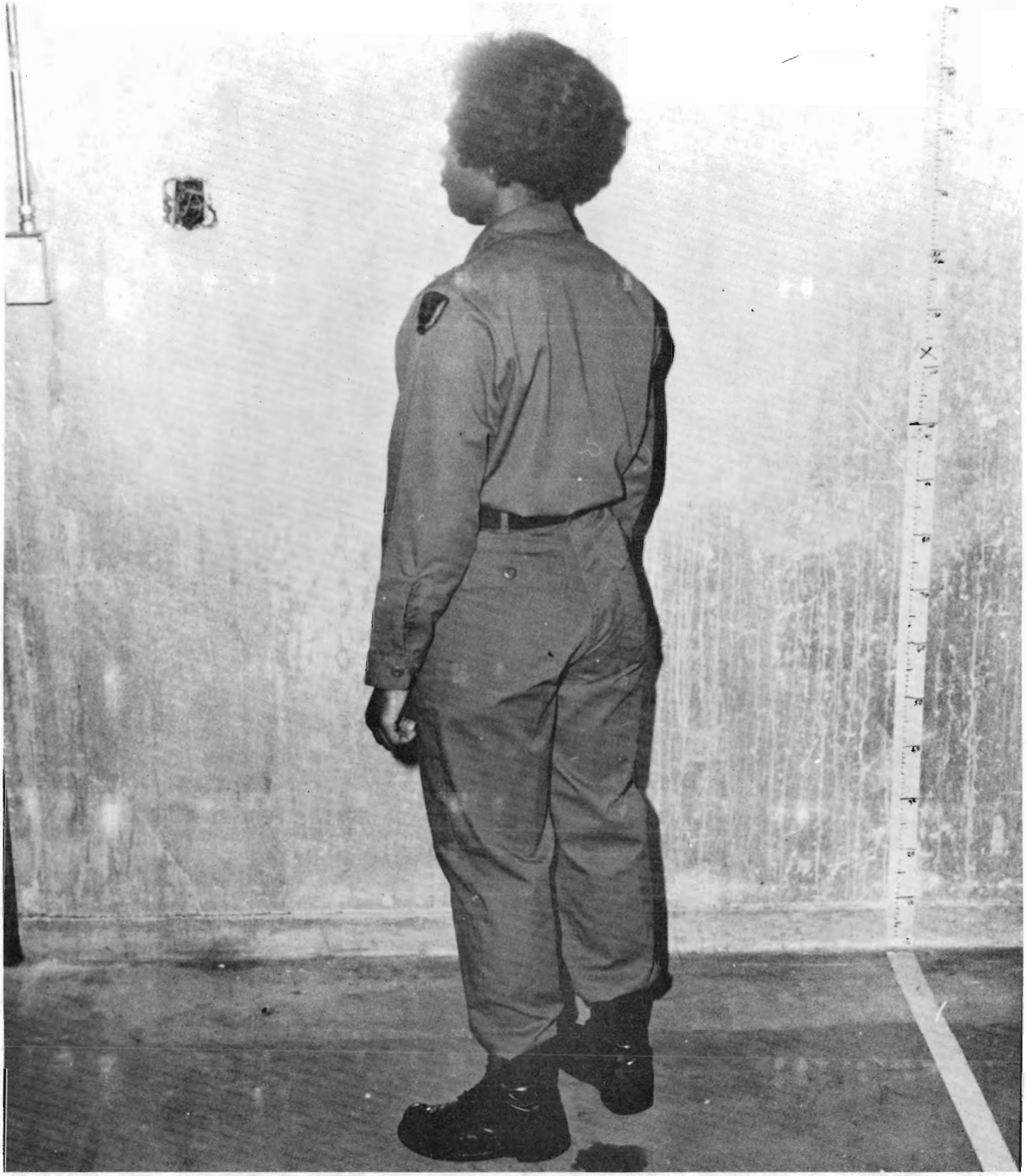

Figure 4. Back view of female subject in No Armor condition.

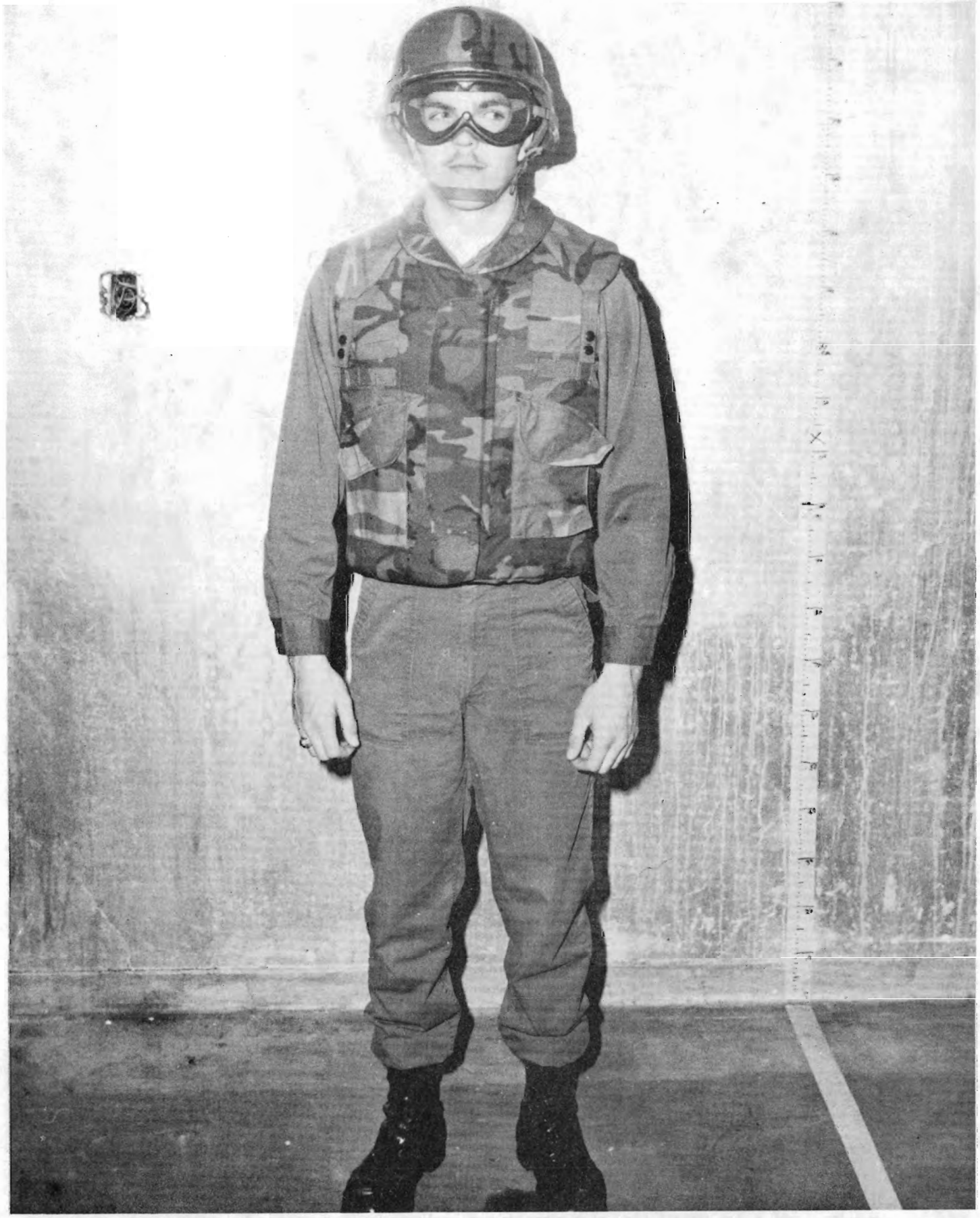

Figure 5. Front view of male subject in Infantry Armor condition.

Figure 6. Back view of male subject in Infantry Armor condition.

Figure 7. Front view of female subject in Infantry Armor condition.

Figure 8. Back view of female subject in Infantry Armor condition.

3. **Commercial A Armor.** This condition consisted of the subject wearing the same clothing as in the No Armor condition with the addition of a four-piece EOD suit manufactured by the Protective Materials Company, Inc. of the United States. This EOD suit is commercially known as the B–900 suit, and includes a helmet with moveable face shield, a vest with rigid chest and back armor plates, a pair of armor leggings, and a pair of armor sleeves. The vest was provided in sizes small, medium, and large. The helmet came in one size with adjustment being accomplished by the inclusion or exclusion of removable foam pads. The sleeves and leggings were not sized. The weights of the components of this suit are presented in Table 2. The size vest each subject wore is presented in Table 1. Photographs of the Commercial A armor condition are presented in Figures 9 and 10 for men and Figures 11 and 12 for women.

4. **Commercial B Armor.** This condition consisted of the subject wearing the same clothing as in the No Armor condition with the addition of a four-piece EOD suit manufactured by the same armor company which manufactured the Commercial A armor. This suit is commercially known as the B–920 suit and is similar in appearance to the Commercial A suit except that the faceshield is thicker (1.2 cm as opposed to 1.0 cm), the sleeves have armor patches over the elbow holes, and the sleeves have an armor bib and collar attached. The leggings, sleeves, collar, and bib of the Commercial B suit are lighter (see Table 2) and thinner (0.5 cm as opposed to 0.8 cm) than the armor material used in the Commercial A suit. Lastly, the chest and back plates of the Commercial B vest are virtually identical to the Commercial A plates, but are heavier (see Table 2). The weights of all the components of this suit are presented in Table 2, and the size Commercial B vest each subject wore is presented in Table 1; sleeves and leggings were not sized. Photographs of the Commercial B armor condition are presented in Figures 13 and 14 for men and Figures 15 and 16 for women.

5. **Commercial C Armor.** This condition consisted of the subject wearing the same clothing as in the No Armor condition with the addition of a six-piece EOD suit manufactured by Galt Glass Laminates Ltd. of Great Britain. The suit is commercially known as the Mark II EOD suit (NATO stock #8470–99–130–3011), and includes a helmet (NATO stock #8740–99–130–3008) with faceshield and communications headset. Helmet size adjustment is accomplished by the inclusion or exclusion of foam pads. The faceshield is adjustable to three positions. The chest plate and pelvic plate are inserted into pockets in the front apron. The front apron includes a high collar, sleeves, and zipper up the back. The back apron attaches to the front apron by means of hook-and-pile fasteners at the shoulders and sides of the front and back aprons. The leggings are worn under the aprons and are hung from adjustable suspenders off the shoulders. The faceshield is 2 cm thick; the aprons and trousers are 0.7 cm thick. The weights of the components of this suit are presented in Table 2; the suit was manufactured and furnished in only one size: large regular. Photographs of the Commercial C Armor condition are presented in Figures 17 and 18 for men and Figures 19 and 20 for women.

6. **Commercial D Armor.** This condition consisted of the subject wearing the same clothing as in the No Armor condition with the addition of a seven-piece EOD suit manufactured by Bristol Composite Materials Engineering Ltd. of Great Britain. The suit is commercially known as the Bristol Bomb Disposal Suit. It consists of the same helmet with faceshield (NATO stock #8740–99–130–3008) and communication headset that is used with the

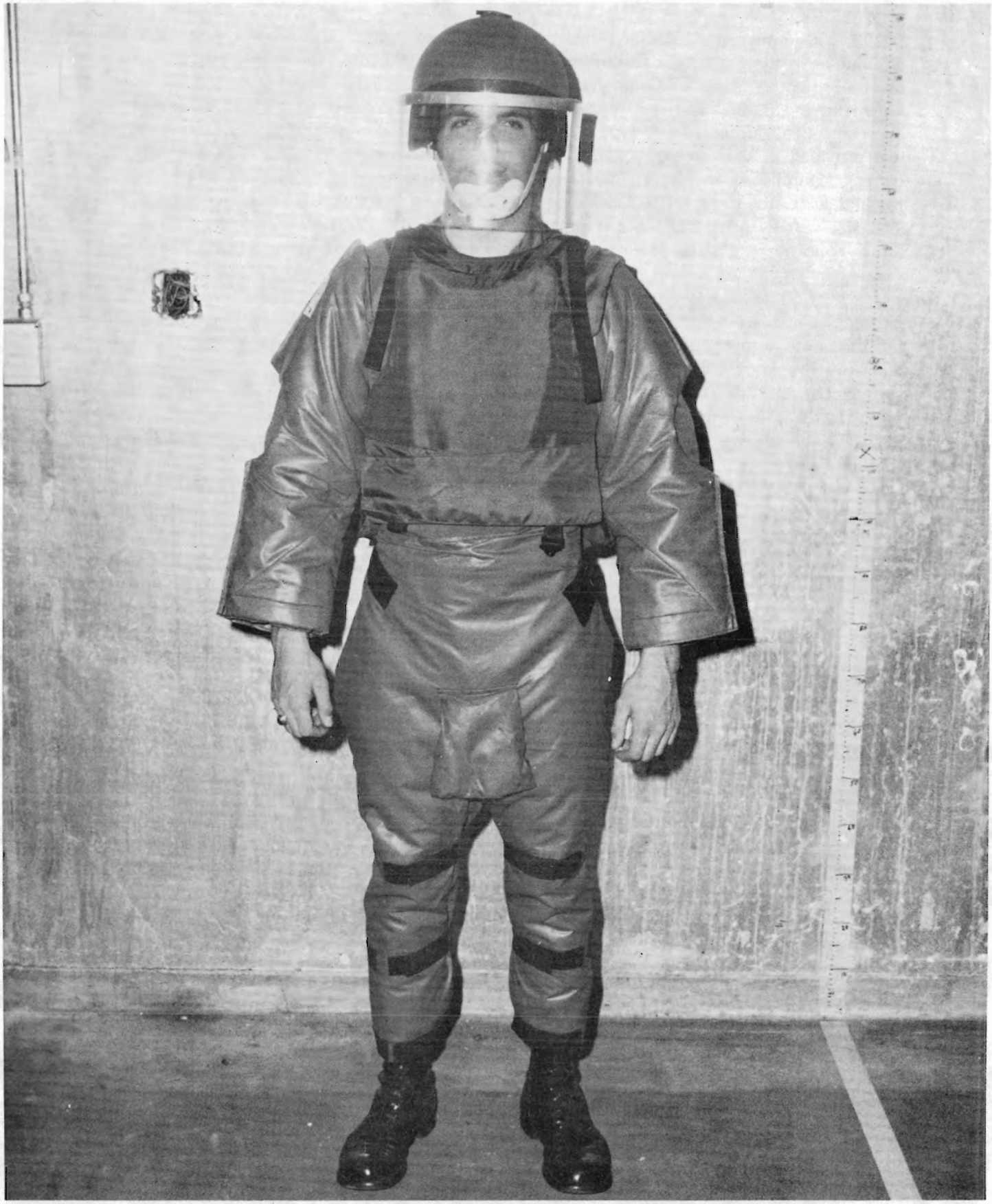

Figure 9. Front view of male subject in Commercial A Armor condition.

Figure 10. Back view of male subject in Commercial A Armor condition.

Figure 11. Front view of female subject in Commercial A Armor condition.

Figure 12. Back view of female subject in Commercial A Armor condition.

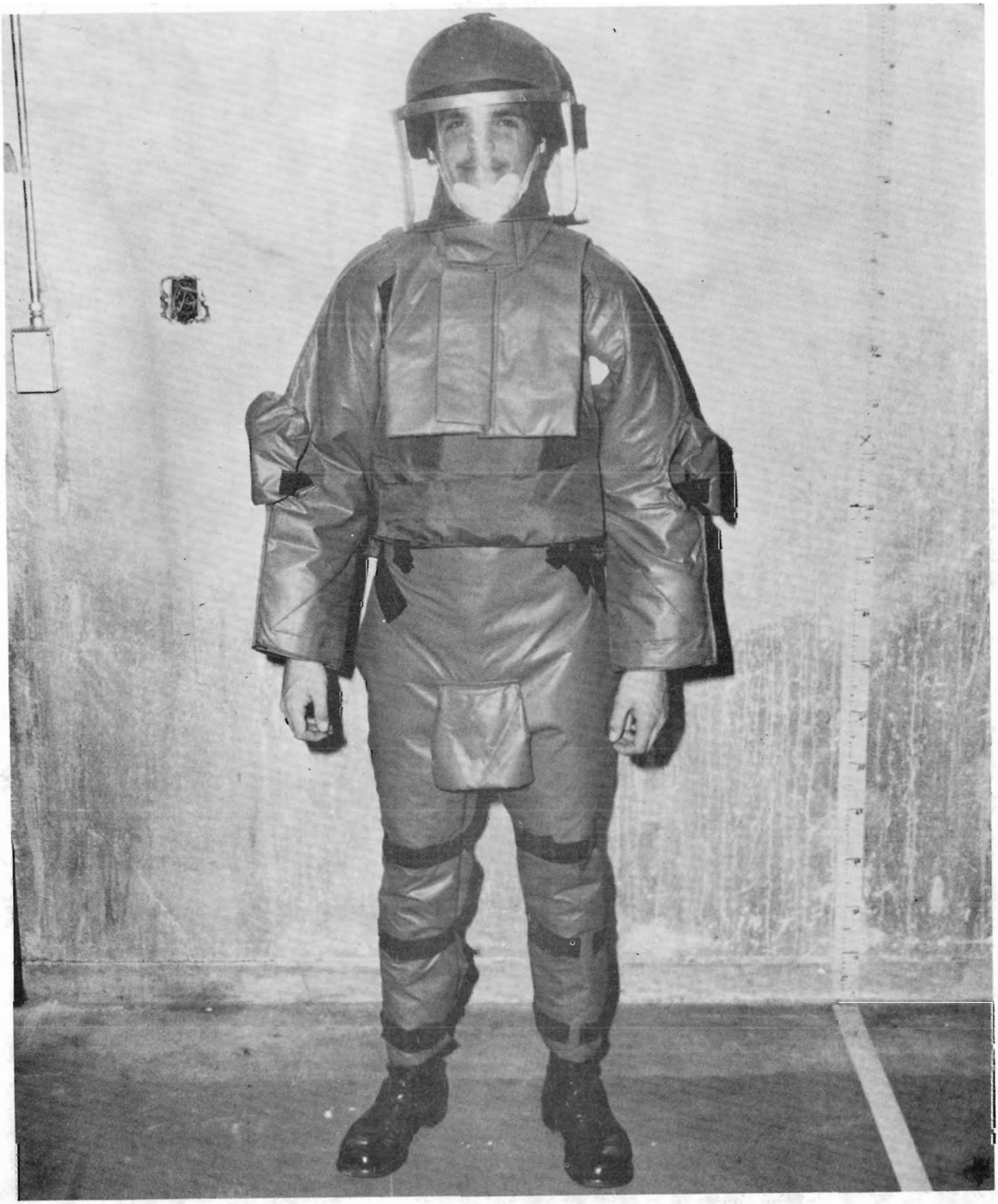

Figure 13. Front view of male subject in Commercial B. Armor condition.

Figure 14. Back view of male subject in Commercial B. Armor condition.

Figure 15. Front view of female subject in Commercial B Armor condition.

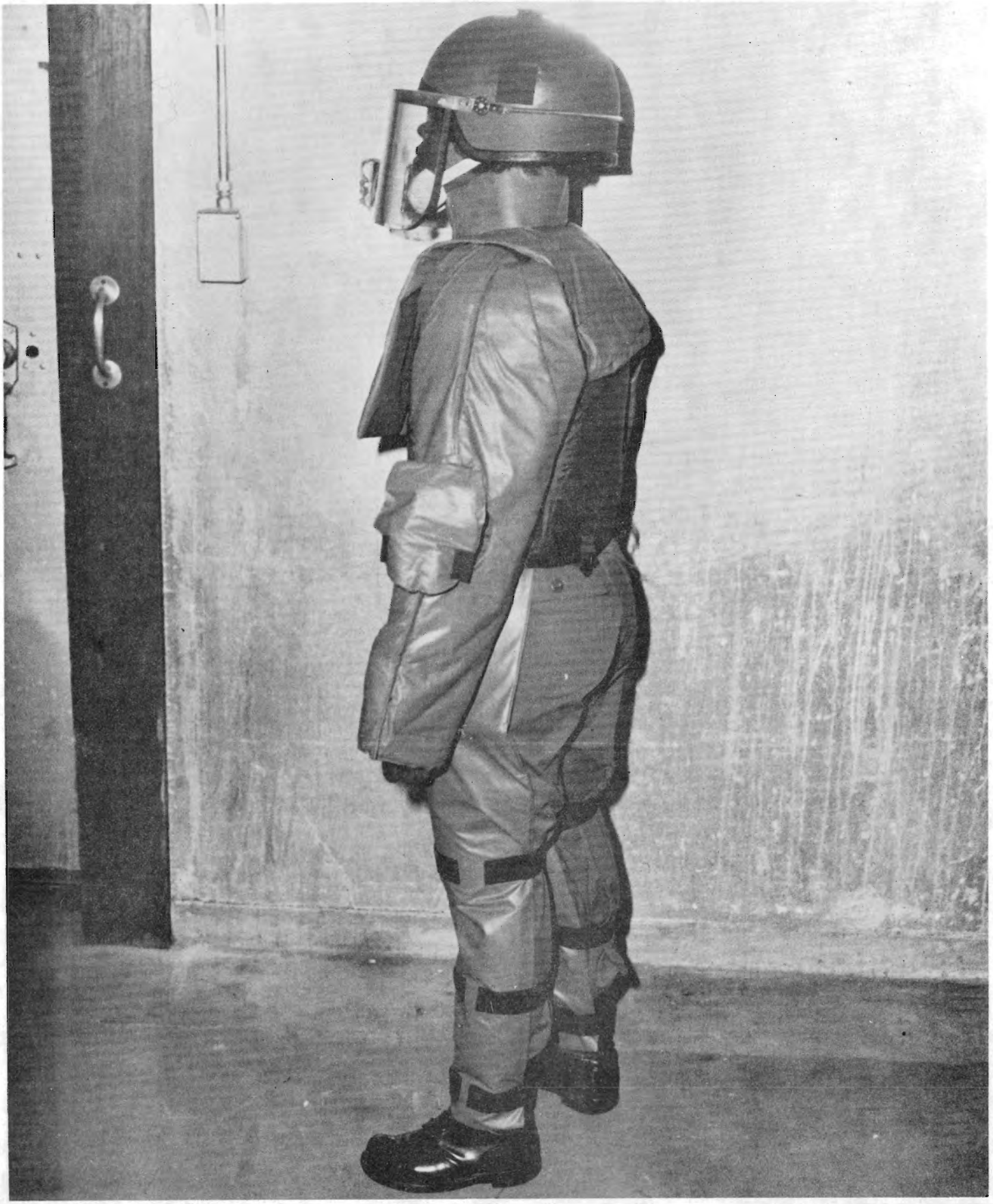

Figure 16. Back view of female subject in Commercial B Armor condition.

Figure 17. Front view of male subject in Commercial C Armor condition.

Figure 18. Back view of male subject in Commercial C Armor condition.

Figure 19. Front view of female subject in Commercial C Armor condition.

Figure 20. Back view of female subject in Commercial C Armor condition.

Commercial C armor. The chest plate is inserted into a pocket on the wraparound apron, while the pelvic plate with cover is attached to the apron by means of strips of hook-and-pile fasteners. The front and back aprons with sleeves are of one piece, 0.7 cm thick. The apron is closed by means of a long hook-and-pile fastener under the left arm of the wearer. The collar is a separate piece and is donned prior to donning the apron. A trauma attenuation vest is worn under the entire garment; this vest is made of 3.5 cm thick spacer fabric. The gaiters extend to the top of the knee and wrap around the entire surface of each leg. The weights of the components of the Commercial D suit are presented in Table 2; the suit was furnished in only one size: large regular. Photographs of the Commercial D armor condition are presented in Figures 21 and 22 for men and Figures 23 and 24 for women.

All 12 subjects were exposed to all six EOD armor conditions and were administered all tests under each armor condition. The methods, results, and discussions of the findings of these tests are presented in the following sections. Section I describes the investigation of gross body mobility. Section II describes the investigation of psychomotor performance and donning/doffing. Section III describes the investigation of speech intelligibility. Section IV describes the investigation of visual field. Section V describes the analysis of subjective report data which were gathered during the course of the entire study. Following Section V, there is a general discussion of the data of all the investigations including the subjective report data.

Figure 21. Front view of male subject in Commercial D Armor condition.

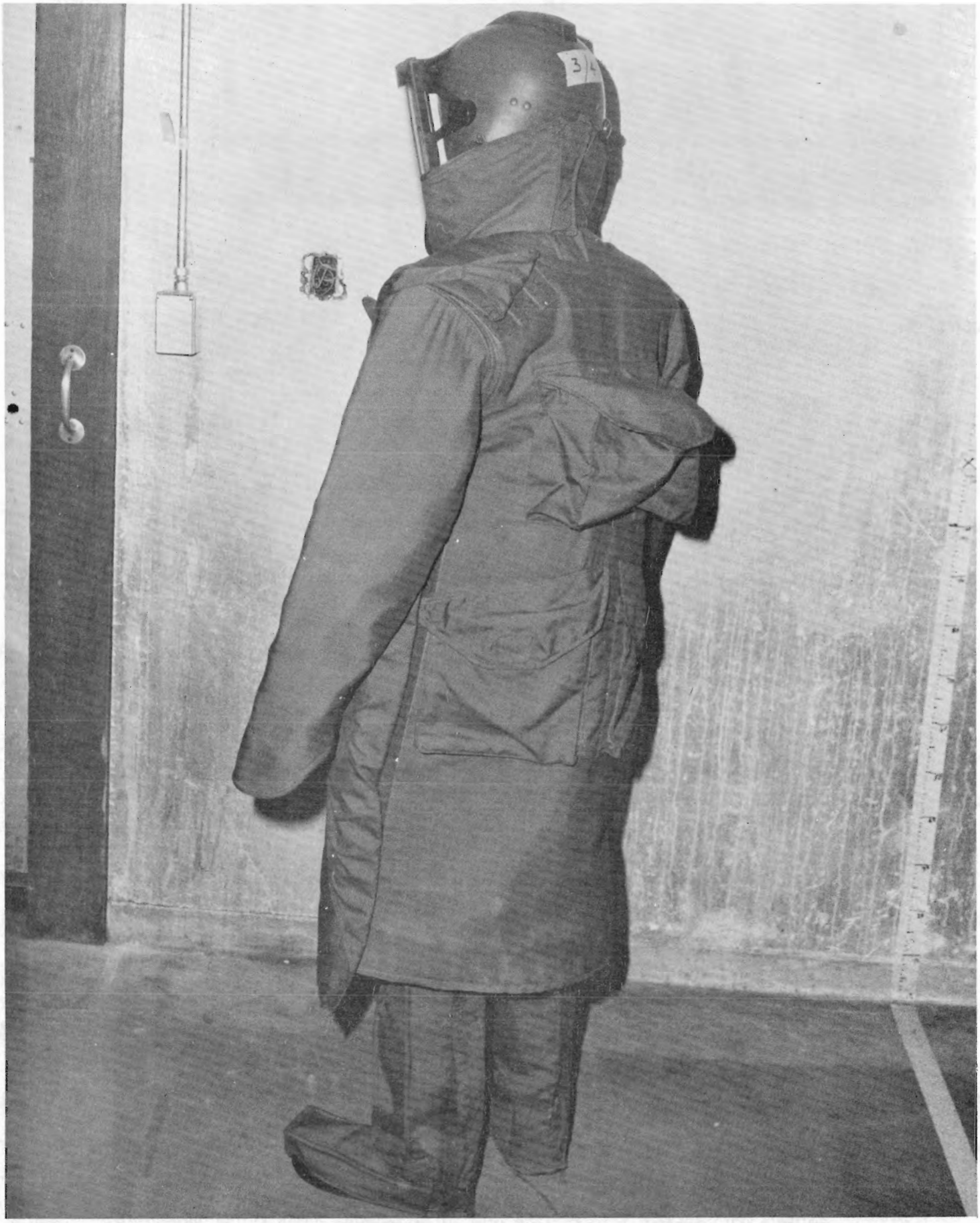

Figure 22. Back view of male subject in Commercial D Armor condition.

Figure 23. Front view of female subject in Commercial D Armor condition.

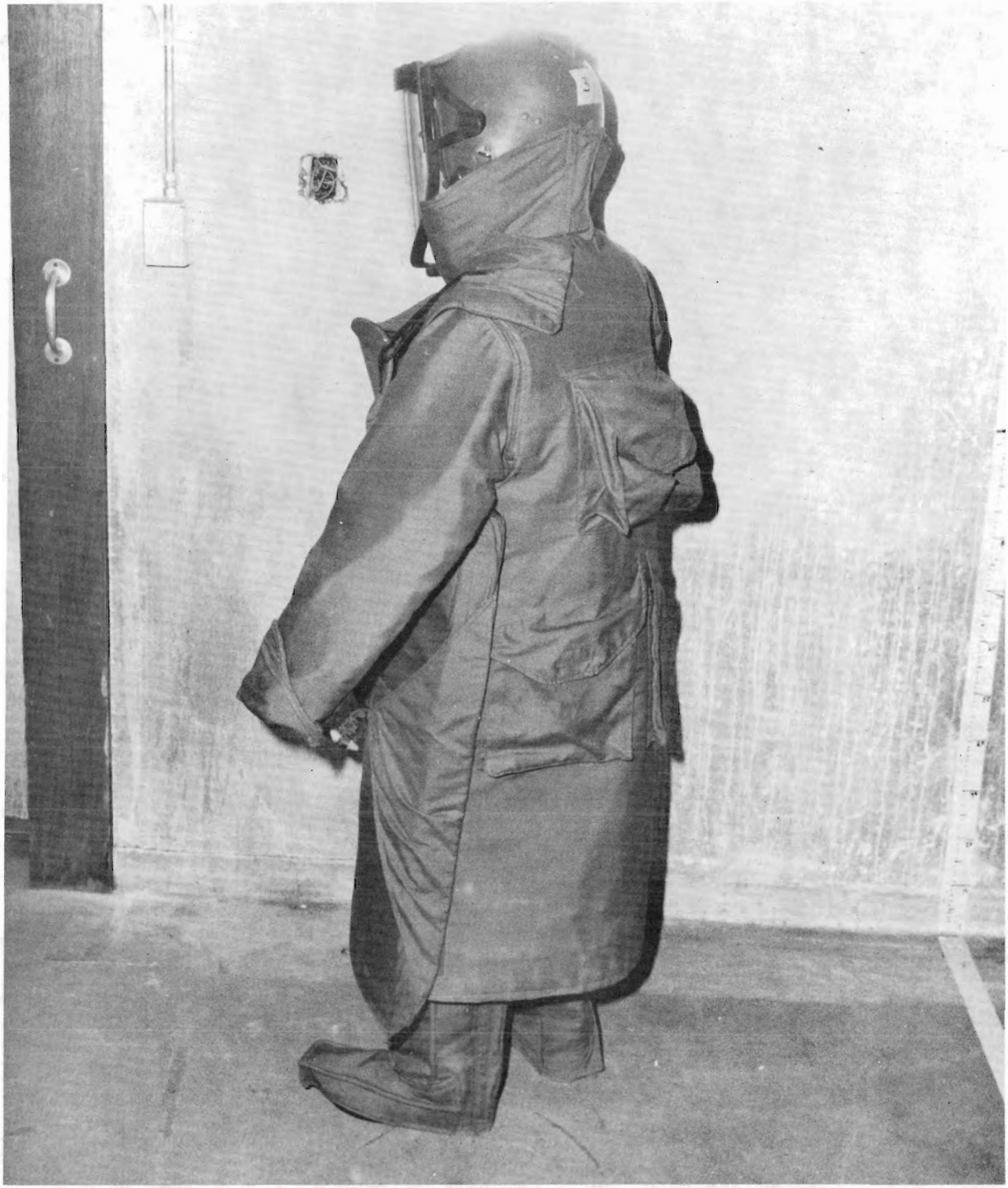

Figure 24. Back view of female subject in Commercial D Armor condition.

I. GROSS BODY MOBILITY INVESTIGATION

Purpose

The purpose in conducting this investigation was to determine whole body freedom of movement of subjects outfitted in EOD armor and to compare this freedom of movement to that permitted when no armor is worn. The performance characteristics addressed in this investigation were: "the total body armor system must – Provide the flexibility necessary for not seriously impeding the wearer" (Letter Requirement, para. 5a(3)) and "Not inhibit head movement" (Letter Requirement, para. 5a(16)).

Subjects

Twelve subjects, six men and six women, were recruited for this investigation. These are the same subjects described in the Introduction section of this report.

Procedure

While attired in each of the six EOD armor conditions, each subject performed a series of 15 gross body movements. The movements are briefly described here and are described in detail in Appendix B.

1. Walk Forward.[2] The subject was instructed to take five steps forward; the distance traveled was measured from the heel of the foot when starting to the toe of the foot taking the fifth step. The subject was instructed to go as far as possible on each step to attain a maximal total distance.

2. Walk Backward.[3] The subject was instructed to take five steps in a backward direction; the distance traveled was measured from the toe of the foot when starting to the heel of the foot taking the last step. The subject was instructed to go as far as possible on each step to attain a maximal total distance.

3. Side Step.[4] The subject was instructed to take five steps in a sideward position, stepping out with the left foot, being careful not to jump, and to bring the right foot up to the left one. The distance traveled was measured from the right side of the right foot before starting to the left side of the left foot after the fifth step.

[2] E. V. Saul and J. Jaffe. Effects of clothing on gross motor performance. Technical Report EP–12. Natick, MA: Quartermaster Research and Development Center, 1965.

[3] Ibid.

[4] See reference 2.

4. **Standing Trunk Flexion.** Keeping the knees stiff, the subject was instructed to bend at the waist and reach down as far as possible. The performance score was the maximal point to which the subject's finger tips reached.

5. **Head Rotation.**[5] The subject was instructed to stand erect, bend at the waist, grab the seat of a chair, and turn the head as far as possible to the left and then to the right. The angle through which the subject's head was able to turn was the performance score.

6. **Ventral-Dorsal Head Flexion.**[6] While sitting in a straight back chair with hands clasped behind the back, the subject was instructed to bend the head down as far as possible (without moving the chest and shoulders) and then tilt the head back as far as possible. The performance score was the magnitude of the angle through which the subject's head was able to move.

7. **Upper Arm Abduction.**[7] While in contact with and standing facing the projecting corner of a wall, the subject was instructed to raise both arms up and sideways as far as possible. The performance score was the magnitude of the angle through which the right arm was able to move.

8. **Upper Arm Forward Extension.**[8] The subject was instructed to stand facing a wall with the right shoulder and arm extending beyond the wall into an opening (for example, a doorway). With the right arm placed against the subject's side, elbow stiff and arm perpendicular to the floor, the subject was instructed to raise the entire arm forward and up as far as possible; the elbow was kept stiff and the trunk was kept erect. The performance score was the magnitude of the angle through which the subject was able to move the arm.

9. **Upper Arm Backward Extension.**[9] The subject was instructed to stand erect with the back against the wall and the right arm and shoulder protruding beyond the wall into an opening (for example, a doorway). With the elbow stiff, the entire arm was pronated (rotated) until the entire palm was facing outward with the thumb pointed dorsally. The subject was instructed to extend the arm backward as far as possible while keeping the elbow stiff and the palm out. The performance score was the magnitude of the angle through which the subject was able to move the arm.

[5] E. R. Dusek and W. H. Teichner. The reliability and intercorrelations of eight tests of body flexion. Technical Report EP–31. Natick, MA: Quartermaster Research and Development Center, 1956.

[6] Ibid.

[7] E. R. Dusek. Standardization of tests of gross motor performance. Technical Report EP–81. Natick, MA: Quartermaster Research and Engineering Center, 1958.

[8] See reference 5.

[9] See reference 2.

10. Upper Leg Abduction.[10] The subject was instructed to stand erect, feet together, facing an upright suport. While grasping the upright support with both hands, the subject was instructed to raise the entire leg sideways and up as far as possible; during this movement, the subject was instructed not to bend the trunk, to keep the knee stiff, and not to rotate the leg. The performance score was the magnitude of the angle through which the subject was able to move the leg.

11. Upper Leg Forward Extension.[11] The subject was instructed to stand erect with the back against a wall, and to grasp an upright support with the left hand for support. The subject was instructed to raise the right leg forward and up as far as possible while keeping the knees stiff and the back against the wall. The performance score was the magnitude of the angle through which the subject was able to move the upper leg.

12. Upper Leg Backward Extension.[12] The subject was instructed to stand erect with the chest against the wall with the right hip and leg protruding beyond the wall into an opening (for example, a doorway). The subject was then instructed to move the upper leg as far backward as possible without moving the chest from the wall and without moving the trunk. The performance score was the magnitude of the angle through which the subject was able to move the upper leg.

13. Upper Leg Flexion.[13] The subject was instructed to stand erect with the back against a wall, legs together and knees stiff. The subject was instructed to raise the upper leg as far as possible and was permitted to let the knee bend freely. The subject had to keep the back against the wall. The performance score was the magnitude of the angle through which the subject was able to move the upper leg.

14. Sitting Trunk Flexion. The subject was instructed to sit erect in a straight back chair and then to bend forward from the waist as far as possible. The performance score was a rating by the experimenter of how erect the subject was able to sit in the chair and bend at the waist.

[10] See reference 2.

[11] J. M. Lockhart and C. K. Bensel. The effects of layers of cold weather clothing and type of liner on the psychomotor performance of men. Technical Report NATICK/TR–77/018. Natick, MA: US Army Natick Research and Development Command, 1977.

[12] See reference 5.

[13] See reference 2.

15. Kneel-and-Rise. The subject was instructed to assume a standing position, then to kneel on both knees, and then to rise to a standing position. The performance score was a rating by the experimenter of how much assistance the subject required in order to resume the standing position.

All testing was conducted in a room maintained at 18.3°C (65°F). Subjects were tested in groups of three with the men and women assigned to separate groups. Each group participated in three, three-hour sessions over a period of two days. During each session, each subject performed all the gross body movements in one EOD armor condition (approximately 75 minutes), took a 30 minute rest break, and performed all the gross body movements for another EOD armor condition (approximately 75 minutes). Each session took a morning or an afternoon to complete. The afternoon of the second day was set aside for make-up if there was a scheduling problem.

The order of presentation of EOD armor conditions was systematically varied from subject to subject so that each armor condition was presented first, second, third, fourth, fifth, and sixth at least once for the males and at least once for the females. With the exception of sitting trunk flexion and kneel-and-rise, all movements were performed four times with the arithmetic mean of the four trials serving as the raw score for data analysis (one practice trial and one test trial were administered for sitting trunk flexion and knee-and rise). Since the long apron of the Commercial D armor prevented use of the goniometer (the device used for measuring angular movement on the upper leg) no data were obtainable in the Commercial D armor condition with respect to the four upper leg movements.

Results

A two-way analysis of variance (Sex x Armor) was performed on each of the first 13 gross body movements (separate analyses were conducted on sitting trunk flexion and kneel-and-rise). Summaries of these analyses of variance are presented in Tables 3 through 15. Armor condition had a significant main effect on all 13 of these movements. The results of Scheffé tests of multiple comparison performed on the means of these movements are presented in Table 16. There were no significant main effects attributable to sex on these 13 movements. However, there were significant interactions between armor and sex on four movements: standing trunk flexion, head rotation, upper arm abduction, and upper leg forward extension. The extent of impairment of sitting trunk flexion and kneel-and-rise varied as a function of armor condition and sex.

1. Walk Forward. The mean distance traveled when the Commercial D armor was worn was significantly less than the mean distance traveled in any other armor condition. The mean distances traveled when Commercial B and Commercial C armor were worn, were significantly less than the distances traveled in the two control conditions (No Armor and Infantry Armor); the distance traveled in Commercial A armor was not different from the two control conditions. The relationships between the armor means are presented in detail in Table 16 and are graphically represented in Figure 25.

Table 3

Summary of Analysis of Variance of
Walk Forward (Five Steps) Data

Source of Variation	df	Mean Square	F	p
Sex (G)	1	53083.7	3.90	
Ss/G	10	13615.4	–	
Armor (E)	5	49851.6	19.97	<.001
G x E	5	1099.9	<1	
Ss x E/G	50	2496.5	–	

Table 4

Summary of Analysis of Variance of
Walk Backward (Five Steps) Data

Source of Variation	df	Mean Square	F	p
Sex (G)	1	24053.6	1.96	
Ss/G	10	12293.2	–	
Armor (E)	5	19222.3	10.96	<.001
G x E	5	442.0	<1	
Ss x E/G	50	1754.5	–	

Table 5

Summary of Analysis of Variance of
Side Step (Five Steps) Data

Source of Variation	df	Mean Square	F	p
Sex (G)	1	58881.7	4.95	
Ss/G	10	11892.7	–	
Armor (E)	5	40799.0	39.28	<.001
G x E	5	1305.4	1.26	
Ss x E/G	50	1038.5	–	

Table 6

Summary of Analysis of Variance of
Standing Trunk Flexion Data

Source of Variation	df	Mean Square	F	p
Sex (G)	1	0.3	<1	
Ss/G	10	132.9	–	
Armor (E)	5	1894.0	74.60	<.001
G x E	5	90.9	3.58	<.01
Ss x E/G	50	25.4	–	

Table 7

Summary of Analysis of Variance of
Head Rotation Data

Source of Variation	df	Mean Square	F	p
Sex (G)	1	3669.4	3.15	
Ss/G	10	1163.8	–	
Armor (E)	5	51281.3	270.96	<.001
G x E	5	585.8	3.10	<.05
Ss x E/G	50	189.3	–	

Table 8

Summary of Analysis of Variance of
Ventral-Dorsal Head Flexion Data

Source of Variation	df	Mean Square	F	p
Sex (G)	1	4.5	<1	
Ss/G	10	956.7	–	
Armor (E)	5	18625.1	87.30	<.001
G x E	5	132.9	<1	
Ss x E/G	50	213.4	–	

Table 9

Summary of Analysis of Variance of
Upper Arm Abduction Data

Source of Variation	df	Mean Square	F	p
Sex (G)	1	300.1	<1	
Ss/G	10	627.7	–	
Armor (E)	5	20264.6	67.51	<.001
G x E	5	770.3	2.57	<.05
Ss x E/G	50	300.2	–	

Table 10

Summary of Analysis of Variance of
Upper Arm Forward Extension Data

Source of Variation	df	Mean Square	F	p
Sex (G)	1	3042.0	1.62	
Ss/G	10	1881.1	–	
Armor (E)	5	21621.2	61.88	<.001
G x E	5	268.2	<1	
Ss x E/G	50	349.4	–	

Table 11

Summary of Analysis of Variance of
Upper Arm Backward Extension Data

Source of Variation	df	Mean Square	F	p
Sex (G)	1	5.6	<1	
Ss/G	10	197.4	–	
Armor (E)	5	1960.5	20.31	<.001
G x E	5	87.2	<1	
Ss x E/G	50	96.5	–	

Table 12

Summary of Analysis of Variance of
Upper Leg Abduction Data

Source of Variation	df	Mean Square	F	p
Sex (G)	1	209.1	<1	
Ss/G	10	431.7	–	
Armor (E)	4	304.9	9.95	<.001
G x E	4	61.6	2.01	
Ss x E/G	40	30.7	–	

Table 13

Summary of Analysis of Variance of
Upper Leg Forward Extension Data

Source of Variation	df	Mean Square	F	p
Sex (G)	1	1372.8	4.02	
Ss/G	10	341.2	–	
Armor (E)	4	368.8	9.50	<.001
G x E	4	103.3	2.66	<.05
Ss x E/G	40	38.8	–	

Table 14

Summary of Analysis of Variance of
Upper Leg Backward Extension Data

Source of Variation	df	Mean Square	F	p
Sex (G)	1	528.1	3.69	
Ss/G	10	143.0	–	
Armor (E)	4	161.4	5.27	<.01
G x E	4	39.9	1.30	
Ss x E/G	40	30.6	–	

Table 15

Summary of Analysis of Variance of
Upper Leg Flexion Data

Source of Variation	df	Mean Square	F	p
Sex (G)	1	2535.0	4.44	
Ss/G	10	570.7	–	
Armor (E)	4	2609.0	47.39	<.001
G x E	4	72.0	1.31	
Ss x E/G	40	55.1	–	

Table 16

Mean Scores for Gross Body Mobility Tasks

Measure	Armor Condition					
	No Armor	Infantry Armor	Commercial EOD Armor A	B	C	D
1. Walk Forward, Five Steps (cm.)	629.3	591.2	564.2	520.4	496.0	442.3
2. Walk Backward, Five steps (cm.)	506.7	477.5	464.8	448.8	446.3	387.0
3. Side Step, Five steps (cm.)	563.2	535.4	523.3	492.2	514.8	394.8
4. Standing Trunk Flexion (cm.)	0.9	1.4	2.8	4.8	19.3	31.6
5. Head Rotation (degrees)	156.1	154.8	138.4	93.7	19.2	14.8
6. Ventral-Dorsal Head Flexion (degrees)	142.2	129.5	129.8	110.6	67.1	44.2
7. Upper Arm Abduction (degrees)	140.8	130.1	118.8	90.4	65.3	34.4
8. Upper Arm Forward Extension (degrees)	149.3	139.1	124.8	96.3	76.2	37.3
9. Upper Arm Backward Extension (degrees)	56.8	49.0	41.7	43.8	28.6	22.5
10. Upper Leg Abduction (degrees)	55.0	54.0	43.8	48.4	45.3	no data
11. Upper Leg Forward Extension (degrees)	59.5	61.2	55.7	55.6	46.8	no data
12. Upper Leg Backward Extension (degrees)	35.1	33.8	28.8	27.0	27.9	no data
13. Upper Leg Flexion (degrees)	87.6	86.5	68.1	67.3	52.5	no data

NOTE: Armor conditions not connected by the same line are significantly different from one another ($p<.05$). Armor conditions above the dotted portion of a line are not to be considered affected by that line; for example, for Upper Leg Backward extension, performance in "B" armor is significantly different from the "No Armor" condition only.

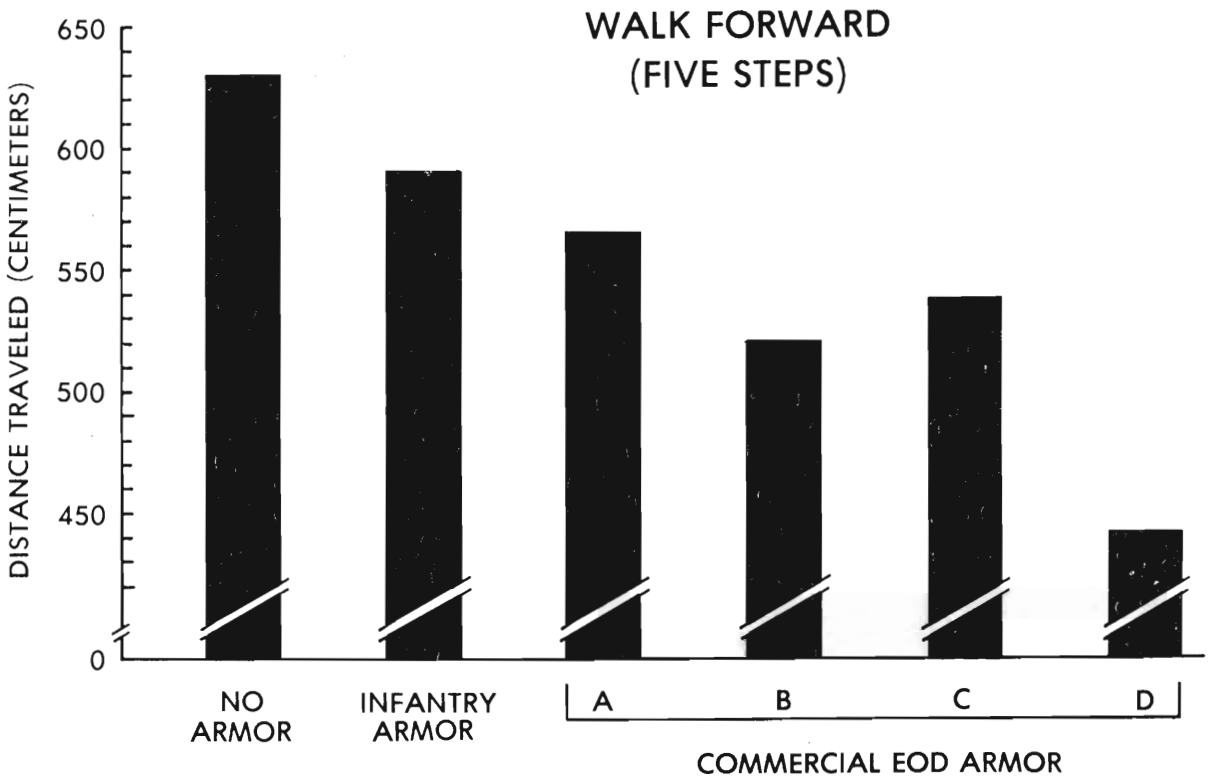

Figure 25. Mean Score on Walk Forward (Five Steps) as a Function of Armor Condition.

2. **Walk Backward.** The mean distance traveled when Commercial D armor was worn was significantly less than the mean distance traveled in any other armor condition. The mean distance traveled when Commercial C armor was worn was significantly less than the distance traveled in the No Armor condition. All other means were not significantly different from one another. The relationships between the armor means are presented in detail in Table 16 and are graphically represented in Figure 26.

3. **Side Step.** The mean distance traveled when Commercial D armor was worn was significantly less than the mean distance traveled in any other armor condition. The mean distances traveled when Commercial B and C armor were worn were significantly less than that in the No Armor control condition. The mean distance traveled in Commercial A armor was not significantly different from either control condition (No Armor or Infantry Armor). The relationships between these armor means are presented in detail in Table 16 and are graphically represented in Figure 27.

4. **Standing Trunk Flexion.** The mean distance from the floor to the fingertips was greatest for the Commercial D armor and next greatest for the Commercial C armor. Both these scores differed from each other and from every other score for the other armor conditions. The mean distance from the floor to the fingertips was less than 5 cm for the remaining four conditions which did not differ from each other. The relationships between these means are presented in detail in Table 16. In addition, there was a significant interaction between sex and armor condition such that the difference between Commercial B and C scores was significant for the women but not for the men. Within each armor condition, there was no significant difference between the men's scores and the women's scores. These relationships are graphically represented in Figure 28.

5. **Head Rotation.** The least amount of head rotation was permitted by Commercial B, C, and D armor; all three of these conditions differed significantly from the two control conditions and the Commercial A armor condition. Head rotation was most reduced by the Commercial C and D armor which, although they did not differ from each other, permitted significantly less head rotation than the Commercial B armor. The relationships between these armor means are presented in detail in Table 16. In addition, there was a significant interaction between sex and armor condition such that the women were more restricted by the Commercial A and B armor than were the men; that is, the women were less able to rotate their heads in the A and B armor than were the men. Also, the women were restricted by the Commercial A armor compared to the two control conditions, while the men were not. These relationships are graphically represented in Figure 29.

6. **Ventral-Dorsal Head Flexion.** The magnitude of head flexion was least for the Commercial D armor and next least for the Commercial C armor. Both of these conditions differed from each other and from all other conditions for head flexion. The only other armor condition to differ from either of the control conditions was the Commercial B armor which permitted significantly less head flexion than the No Armor control, but not less than the Infantry Armor condition. The relationships between these armor means are presented in detail in Table 16 and are graphically represented in Figure 30.

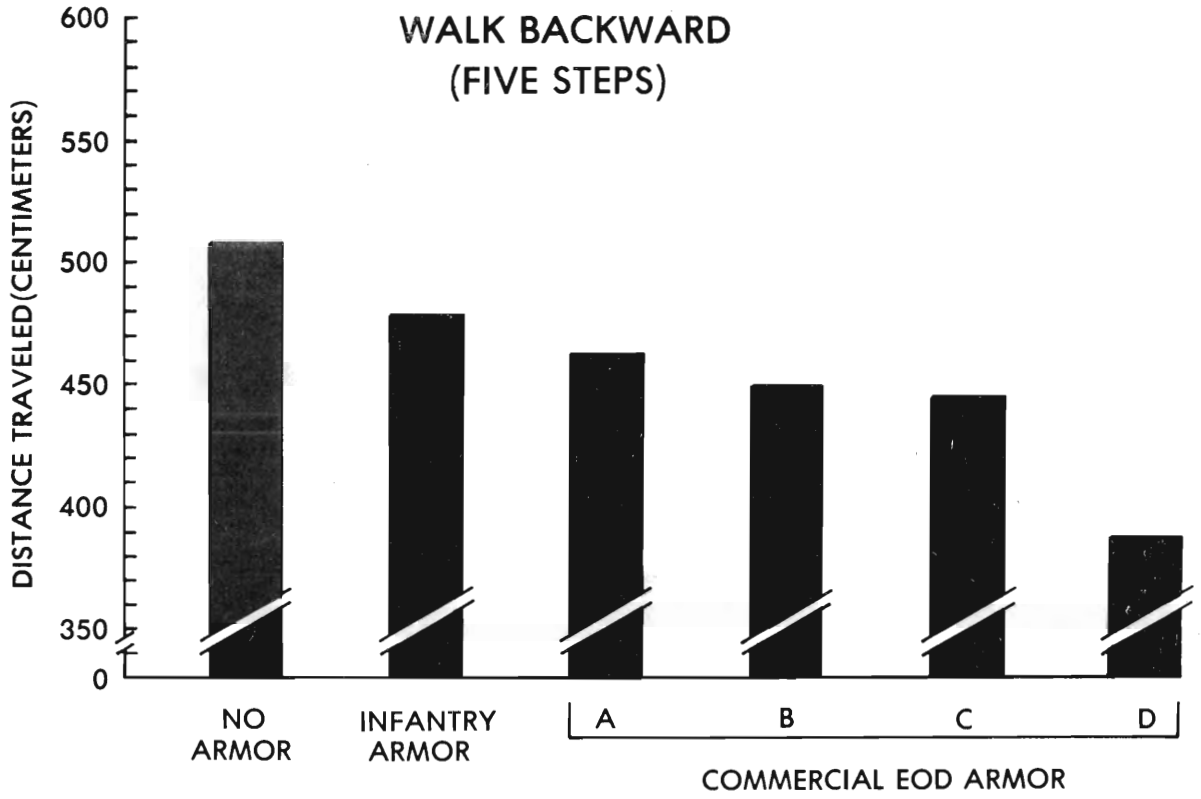

Figure 26. Mean Score on Walk Backward (Five Steps) as a Function of Armor Condition.

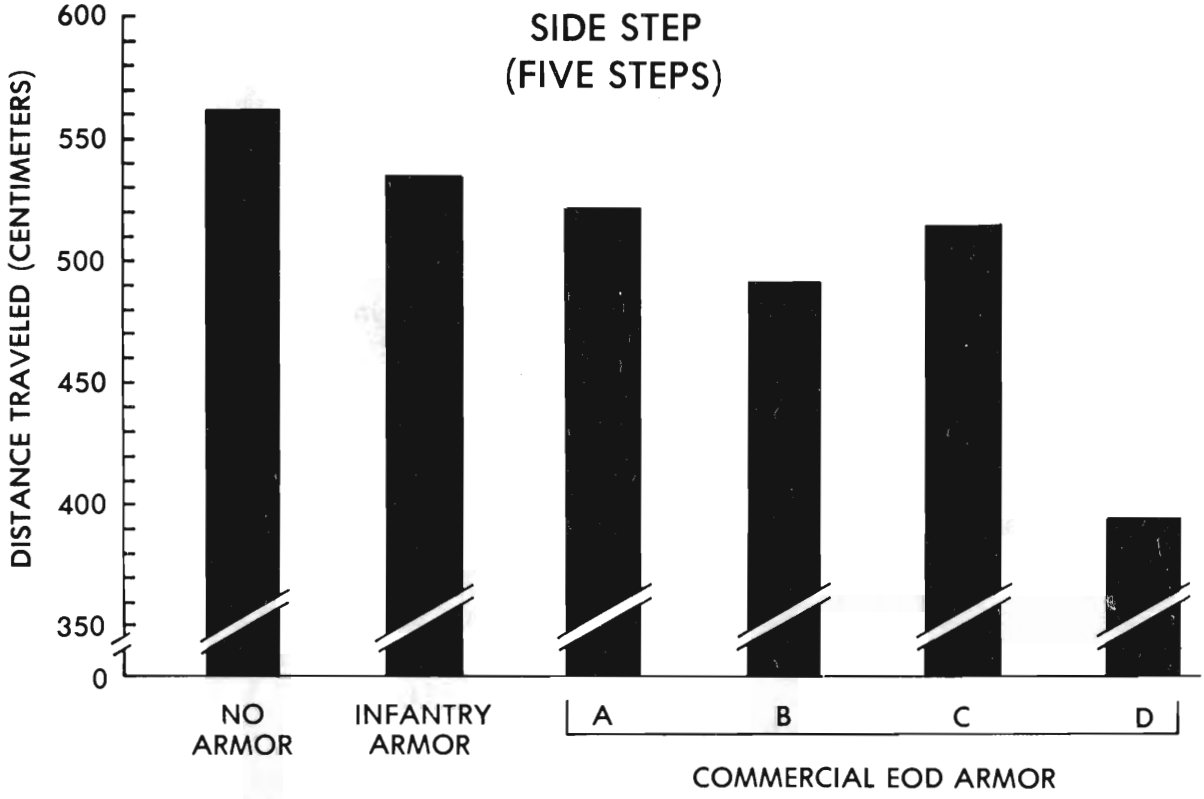

Figure 27. Mean Score on Side Step (Five Steps) as a Function of Armor Condition.

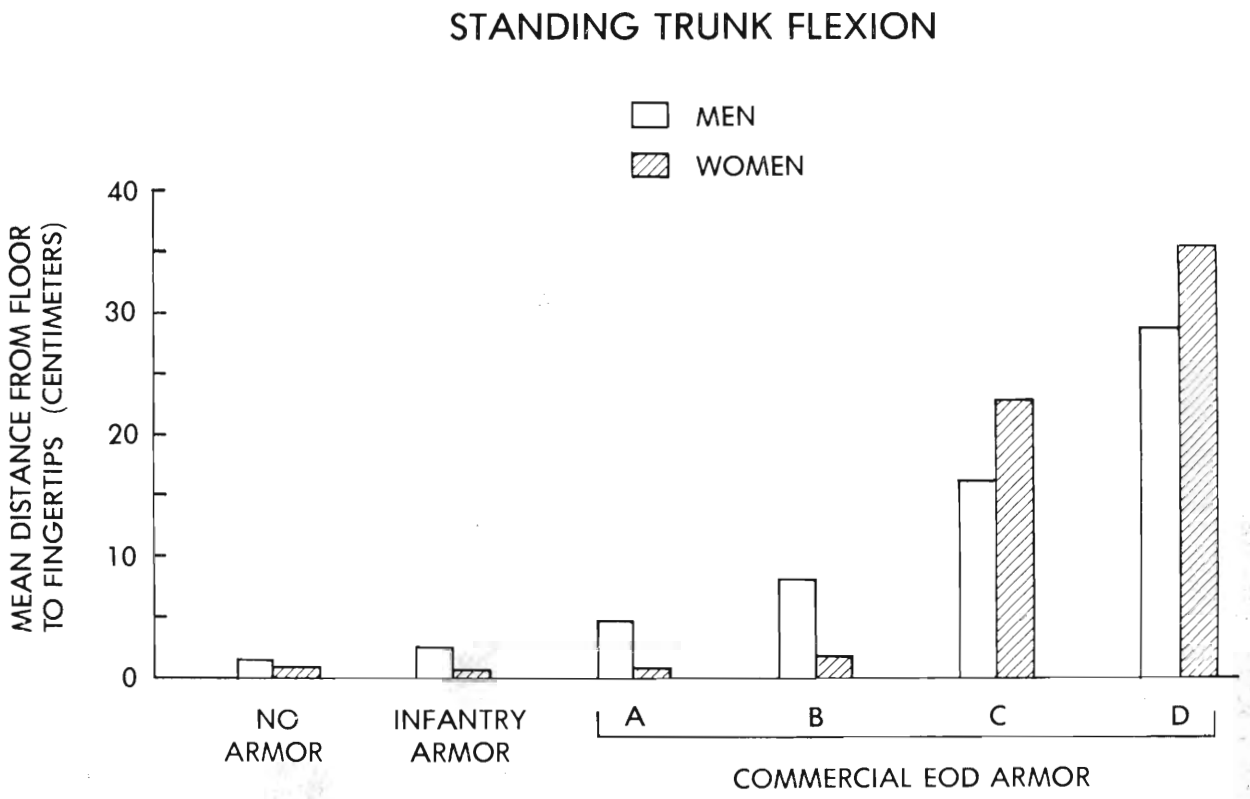

Figure 28. Mean Score on Standing Trunk Flexion as a Function of Armor Condition and Sex.

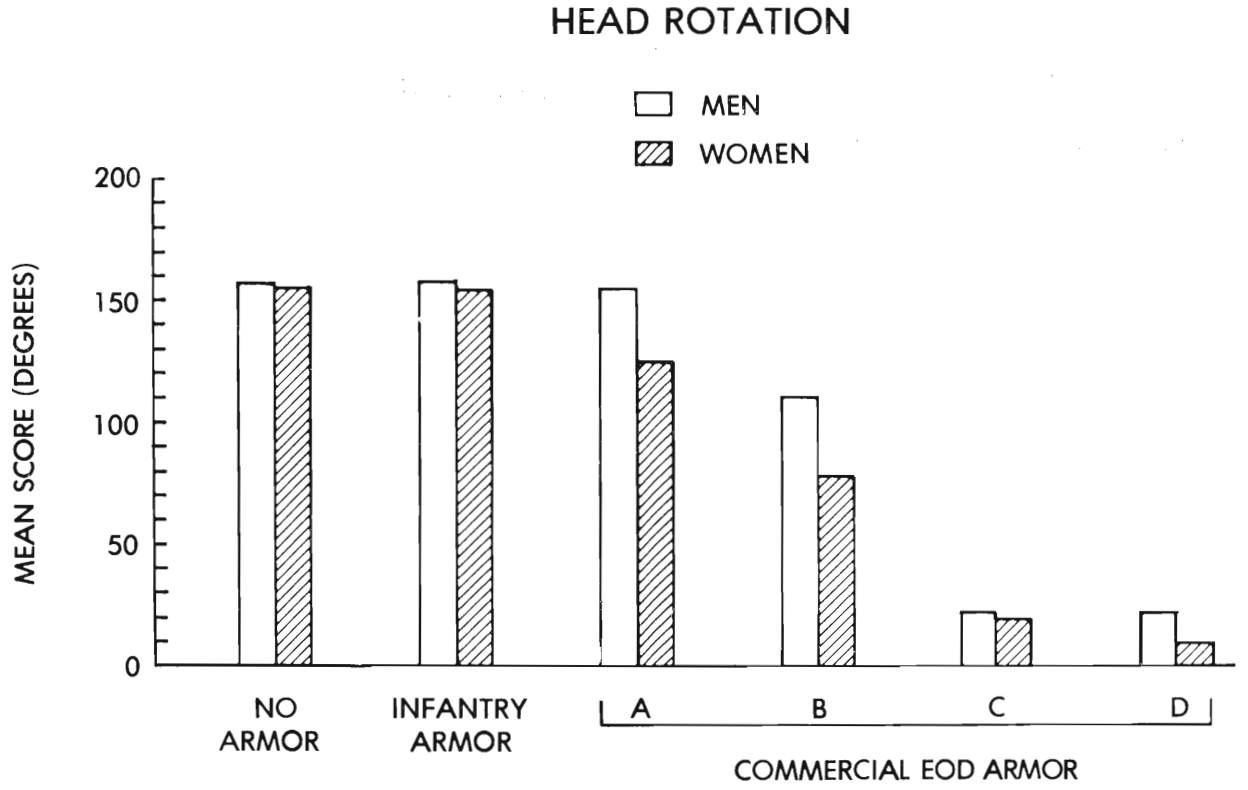

Figure 29. Mean Score on Head Rotation as a Function of Armor Condition and Sex.

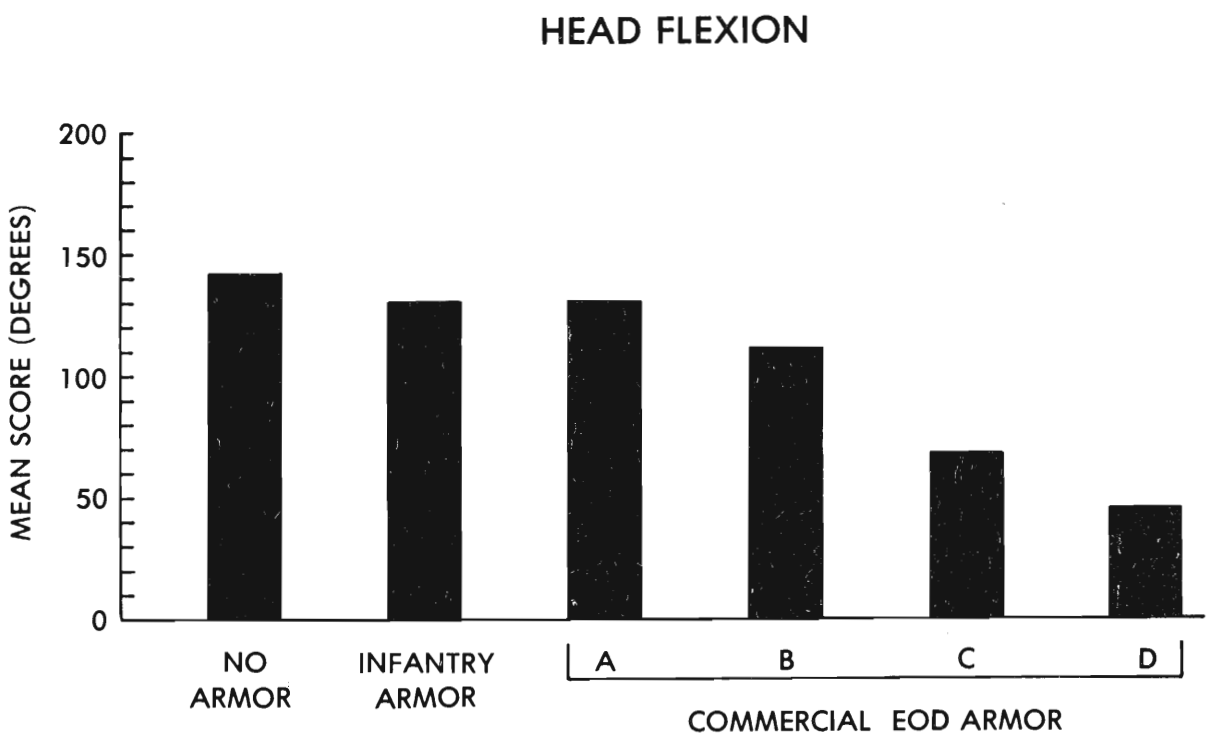

Figure 30. Mean Score on Head Flexion as a Function of Armor Condition.

7. **Upper Arm Abduction.** Compared to the two control conditions, upper arm abduction was significantly affected by Commercial B, Commercial C, and Commercial D armor; all three conditions permitted significantly less upper arm abduction than the No Armor, Infantry Armor, and Commercial A armor conditions. Commercial B, C, and D armor conditions were significantly different from each other such that progressively less abduction was permitted by the Commercial B, C, and D armor, respectively. The relationships between these means are presented in detail in Table 16. In addition, there was a significant interaction between sex and armor condition such that the magnitudes of the differences between Commercial C and D armor and between Commercial A and B armor were significant for the women but not for the men. Within each armor condition, however, there was no significant difference between the men's scores and the women's scores. These relationships are graphically represented in Figure 31.

8. **Upper Arm Forward Extension.** The mean score on upper arm forward extension when the Commercial D armor was worn was significantly less than the mean score in any other armor condition. The mean scores obtained in Commercial B and C armor were not significantly different from one another, but were significantly more than the Commercial D armor and significantly less than the No Armor, Infantry Armor, and Commercial A armor conditions (which did not differ from one another). The relationships between these armor means are presented in detail in Table 16 and are graphically represented in Figure 32.

9. **Upper Arm Backward Extension.** The mean score on upper arm backward extension the Commercial D armor worn was significantly less than all other armor conditions with the exception of the Commercial C armor condition. The Commercial C armor condition permitted significantly less upper arm backward extension than both control conditions and the Commercial B condition. The only other Commercial armor condition to differ from either of the control conditions was the Commercial A armor condition which permitted less movement than the No Armor condition, but not less than the Infantry Armor condition. The relationships between these armor means are presented in detail in Table 16 and are graphically represented in Figure 33.

10. **Upper Leg Abduction.** Because of the long apron on the Commercial D armor, the goniometer (the device used for measuring angular movement) could not be used with that armor condition. Of the remaining conditions, Commercial A and Commercial C armor permitted significantly less upper leg abduction than did the two control conditions. Commercial B armor did not differ from the two control conditions on this movement. The relationships between these armor means are presented in detail in Table 16 and are graphically represented in Figure 34.

11. **Upper Leg Forward Extension.** Because of the long apron on the Commercial D armor, the goniometer could not be used with that armor condition. Of the remaining conditions, the Commercial C armor permitted significantly less upper leg forward extension than all the other armor conditions, none of which differed from one another. The relationships between these armor means are presented in detail in Table 16. In addition, there was a significant interaction between sex and armor condition such that, for the women, there were no statistically significant differences among armor conditions, while the men scored significantly

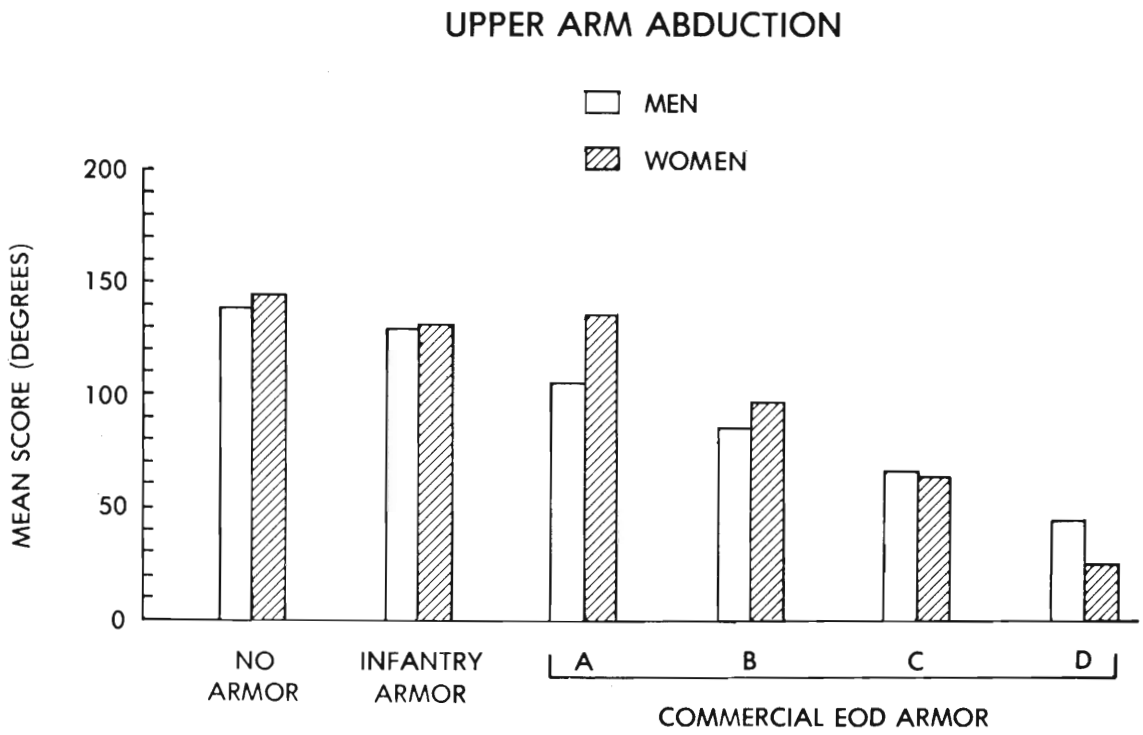

Figure 31. Mean Score on Upper Arm Abduction as a Function of Armor Condition and Sex.

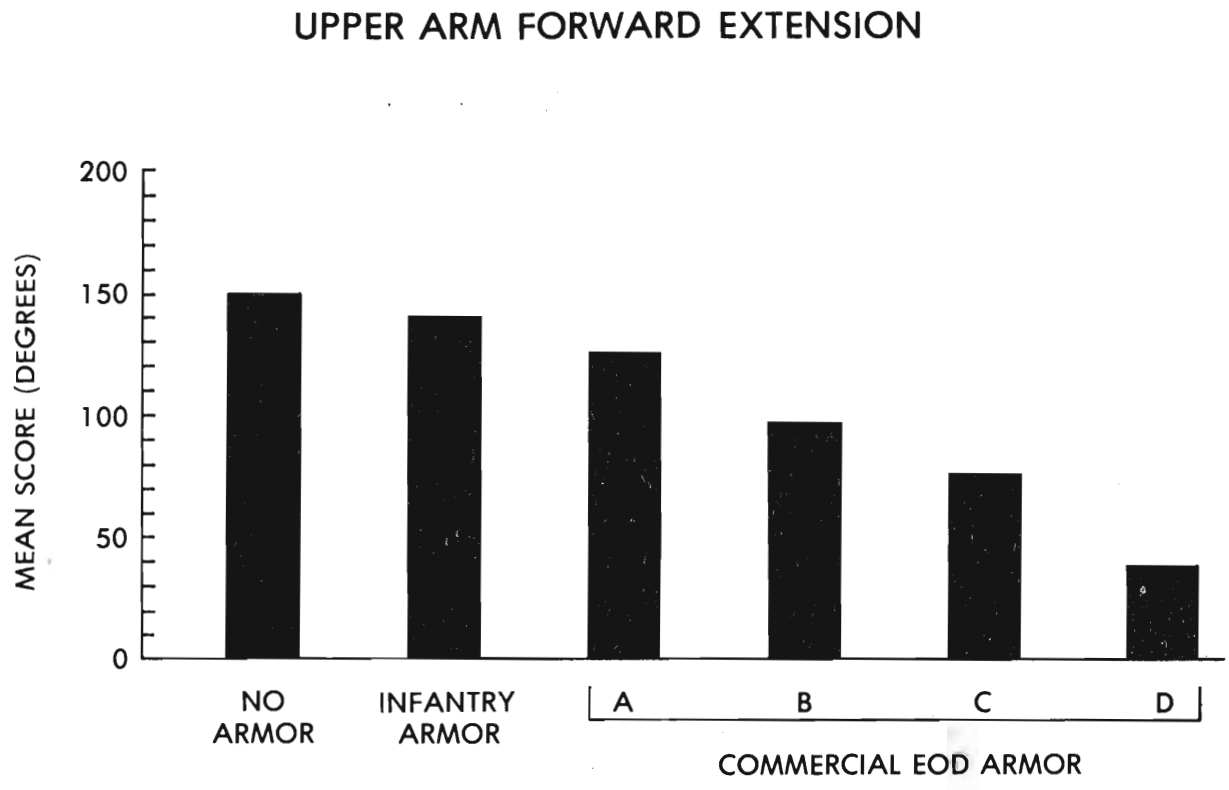

Figure 32. Mean Score on Upper Arm Forward Extension as a Function of Armor Condition.

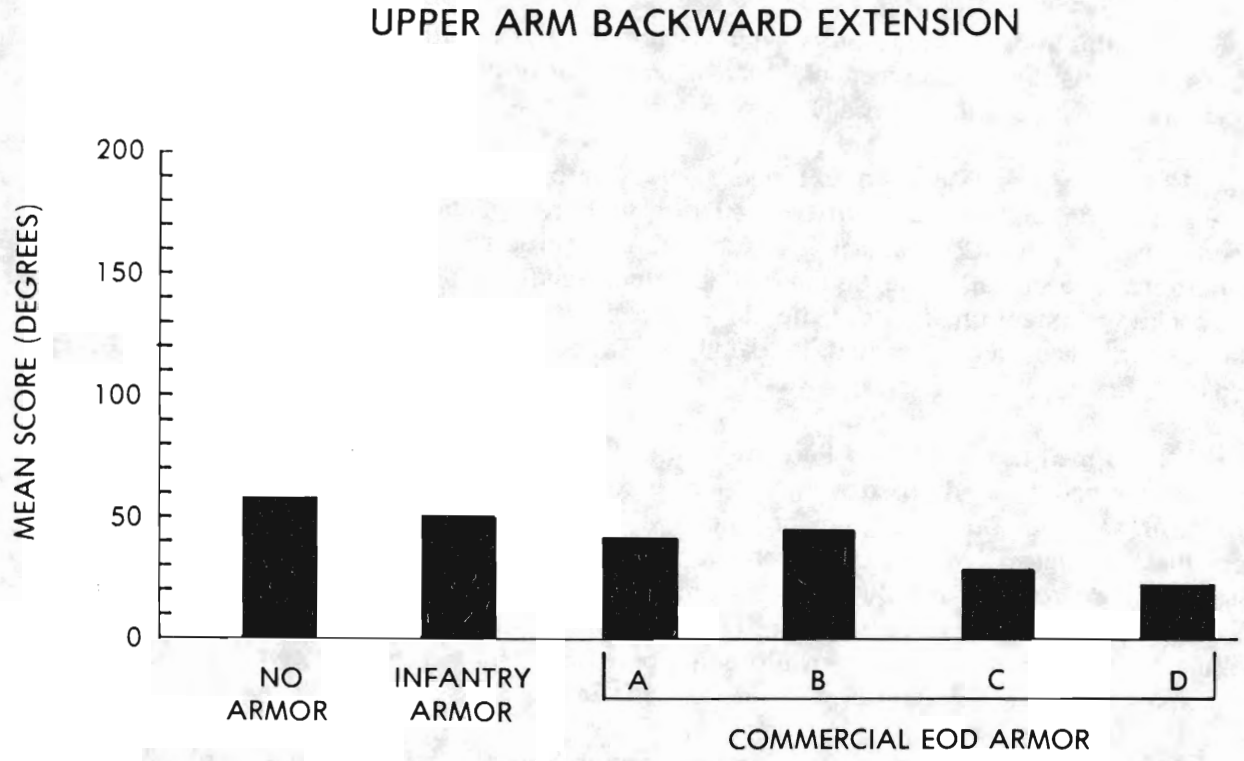

Figure 33. Mean Score on Upper Arm Backward Extension as a Function of Armor Condition.

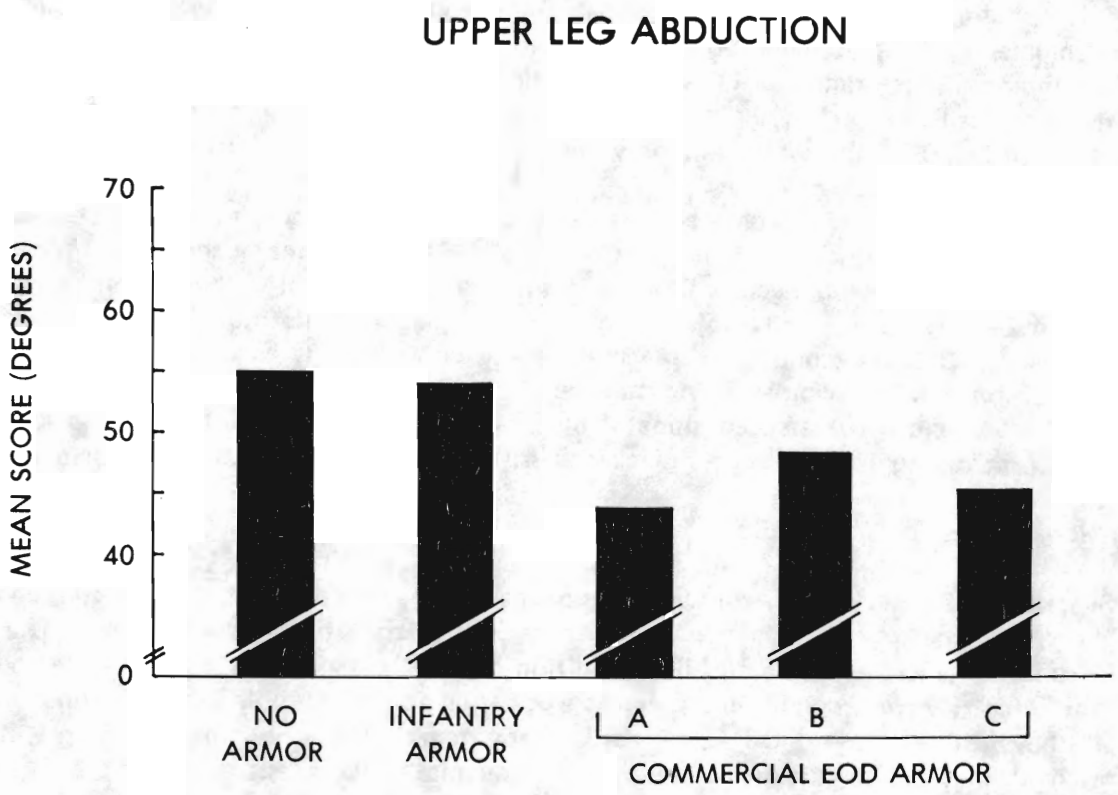

Figure 34. Mean Score on Upper Leg Abduction as a Function of Armor Condition.

poorer on this movement in Commercial C armor than in either of the control conditions. Men's performances in Commercial A and B armor did not differ from the control conditions. These relationships are graphically represented in Figure 35.

12. Upper Leg Backward Extension. Because of the long apron on the Commercial D armor, the goniometer could not be used with that armor condition. Of the remaining armor conditions, only the Commercial B armor differed significantly from either of the two control conditions. Specifically, the Commercial B armor condition permitted significantly less upper leg backward extension than did the No Armor control condition. The relationships between the armor means are presented in detail in Table 16 and are graphically represented in Figure 36.

13. Upper Leg Flexion. Because of the long apron on the Commercial D armor, the goniometer could not be used with that armor condition. Of the remaining armor conditions, the mean amount of upper leg flexion when the Commercial C armor was worn was significantly less than the mean amount of movement in any other armor condition. The mean upper leg flexion scores afforded by the Commercial A and B armor conditions did not differ from one another, but both did differ significantly from the mean amounts of movement measured in the control conditions. The relationships between the armor means are presented in detail in Table 16 and are graphically represented in Figure 37.

14. Sitting Trunk Flexion. All subjects in the two control conditions, as well as those in the Commercial A and B armor conditions, were able to perform this movement (sit upright in a chair and then bend forward at the waist). With the exception of two women (who could sit upright in the chair, but were unable to bend forward at the waist), all subjects in the Commercial C armor condition were able to perform this movement. Much difficulty was encountered in the Commercial D armor condition, with the women being more encumbered than the men: all but two of the men could bend forward at the waist; none of the women could bend forward at the waist and only one of them could sit upright in the chair.

15. Kneel-and-Rise. All subjects were able to perform this movement unassisted in the two control conditions as well as in the Commercial A and B armor conditions. With the exception of one man who needed to hold a support (the back of a chair) with one hand in order to be able to rise, all subjects were able to perform this movement unassisted in the Commercial C armor condition. Much difficulty was encountered in the Commercial D armor condition with the women being more encumbered than the men: all but one of the men could kneel and rise unassisted; none of the women could rise without grasping a support and two of them required the experimenter's assistance to rise to a standing position.

Discussion

Since there is no standard Army EOD armor against which to compare the four commercial EOD suits, the No Armor and the Infantry Army control conditions were included. The No Armor condition represents the real-life condition of EOD personnel as they operate today, while the Infantry Armor condition represents a potential armor ensemble EOD personnel could wear if they utilized current US Army stock armor items. Therefore, the following will be used as guidelines for discussion of the four commercial EOD suits.

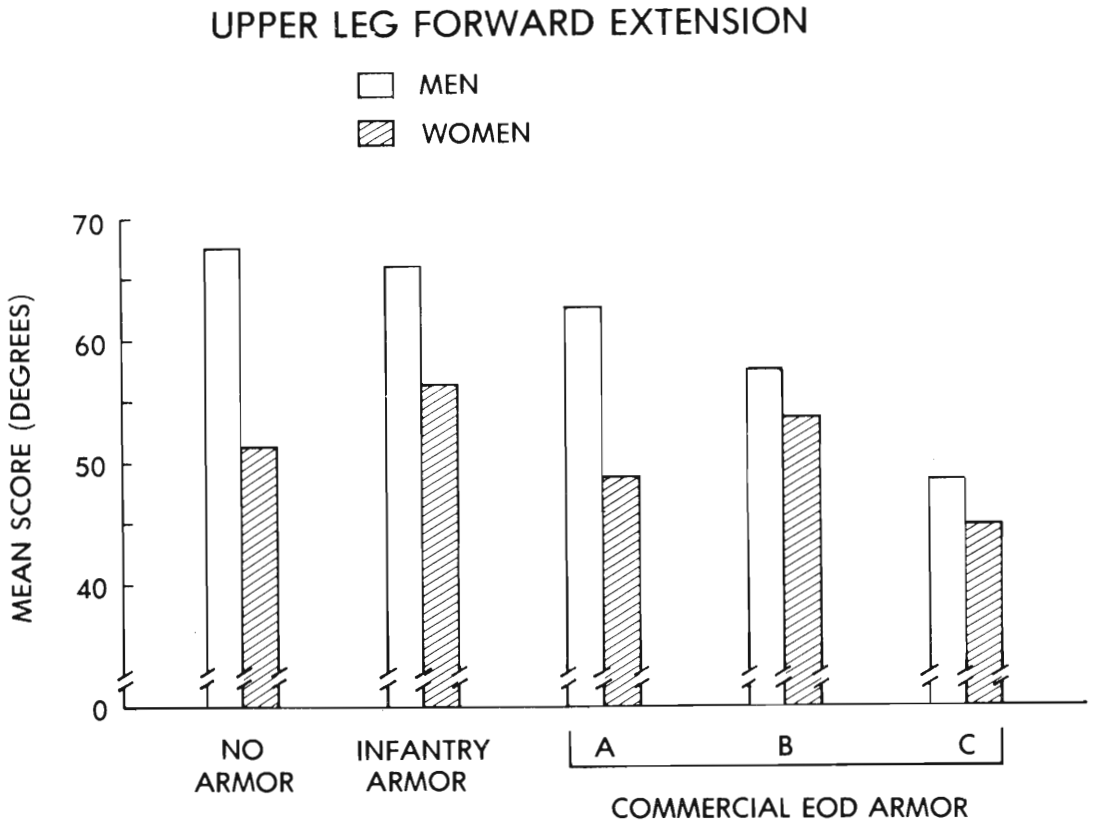

Figure 35. Mean Score on Upper Leg Forward Extension as a Function of Armor Condition and Sex.

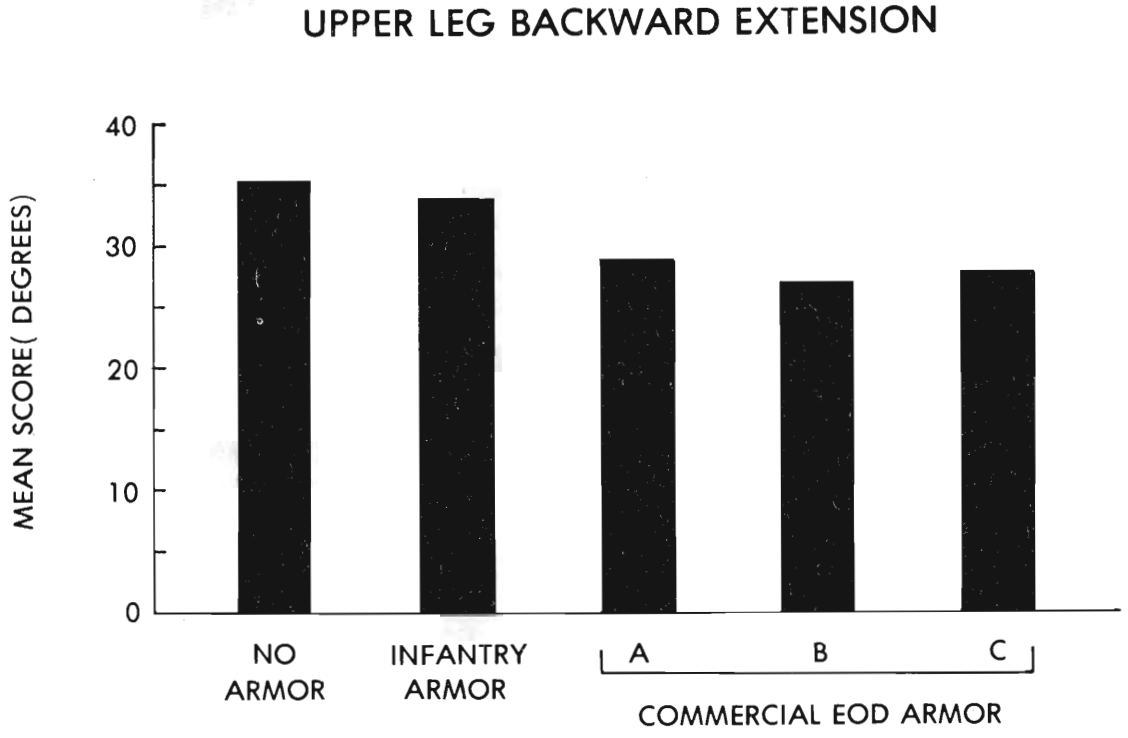

Figure 36. Mean Score on Upper Leg Backward Extension as a Function of Armor Condition.

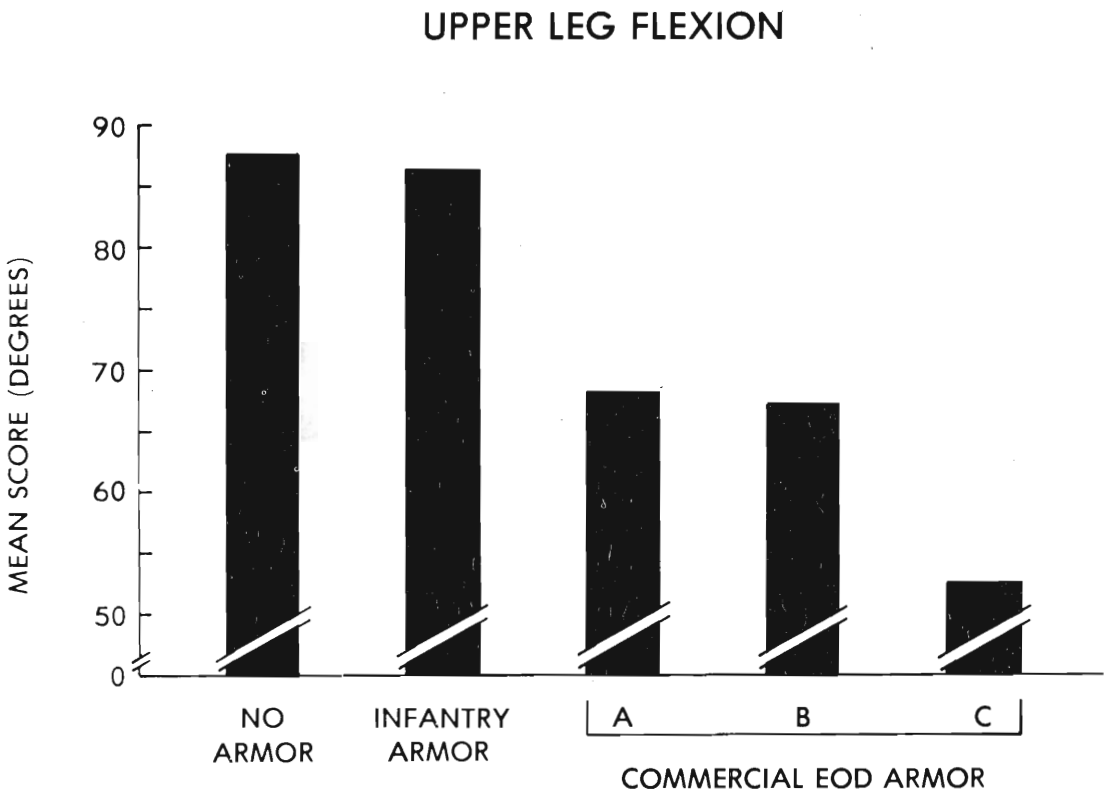

Figure 37. **Mean Score on Upper Leg Flexion as a Function of Armor Condition.**

1. If, with respect to gross body mobility and freedom of head movement, subject performance in a particular commercial EOD suit does not differ from subject performance in the No Armor control condition, **it may be stated that the suit conforms with the relevant performance characteristics of the Letter Requirement** (namely, paragraphs 5a(3) and 5a(16)).

2. If, with respect to gross body mobility and freedom of head movement, subject performance in a particular commercial EOD suit is not as good as that in the No Armor control condition, but is as good as (or better than) performance in the Infantry Armor control condition, **it may be stated that the suit marginally conforms with the relevant performance characteristics of the Letter Requirement** (namely, paragraphs 5a(3) and 5a(16)).

Each of the four commercial EOD suits is discussed below in comparison with the No Armor and the Infantry Armor control conditions.

Commercial A Armor. In general, the Commercial A armor conforms with the relevant gross body mobility and freedom of head movement performance characteristics of the Letter Requirement. On 12 of the 15 movements, subjects performed just as well in Commercial A armor as they did in the No Armor control condition. The three movements which were not performed as well as in the No Armor condition were upper arm backward extension, upper leg abduction, and upper leg flexion. Upper arm backward extension was most likely inhibited because the arm (which was in an armor sleeve) met the resistance of the vest's back armor plate as the arm moved rearward. Partially removing the edge of the back armor plate to make it smaller in the shoulder area, as well as decreasing the thickness of the armor sleeve in the dorsal area of the shoulder, may facilitate this type of rearward movement of the arm; nevertheless, since upper arm backward extension in Commercial A armor was no different from the magnitude of this same movement in the Infantry Armor condition, it may be stated that upper arm backward extension in Commercial A armor is marginally acceptable. Upper leg abduction and upper leg flexion in Commercial A armor were significantly poorer than in the No Armor control condition and were also significantly poorer than in the Infantry Armor control condition. Inhibition of upper leg abduction was probably due to the low inflexible crotch of the pants (the plastic-like outer material of the pants was torn by subjects making this movement), while the inhibition of upper leg flexion was probably due to the stiff, inflexible armor material of the pants. Increasing the crotch height of the pants, as well as making the legging armor moveable at the knee (possibly by severing each pant leg at the knee and joining the two pieces with flexible material), may increase the magnitude of both these movements.

Commercial B Armor. Subjects performed as well in the Commercial B armor as they did in the No Armor condition on only six of the 15 gross body movements. Therefore, it may be said that Commercial B armor generally does not conform with the performance characteristics of the Letter Requirement which pertain to gross body mobility and freedom of head movement. However, if one considers subject performance in Commercial B armor as compared to performance in Infantry Armor, it may be stated that the Commercial B armor approaches marginal conformity because it was poorer than Infantry Armor on only six of the 15 gross body movements.

Head rotation and head flexion were severely inhibited in Commercial B armor; this restriction of head movement was not due to the helmet system (the helmet was almost the same as the one used in Commercial A armor), but rather it was due to the stiff, tight-fitting collar of the Commercial B suit of armor. Head movement would be facilitated in this condition if the collar were modified to make it more loose and flexible. Upper arm movements, especially forward extension and abduction, were restricted by the Commercial B suit of armor. This was most likely due to the fact that the sleeve joins the "bib" material at a point midway between the neck and the arm-shoulder joint, thus inhibiting flexibility in the area of the arm-shoulder joint area. Arm movements may be improved with the Commercial B armor system if the joining of the sleeve to the "bib" were done in the area of the arm-shoulder joint. Two leg movements, walking forward and upper leg flexion, were inhibited by the Commercial B suit of armor. Impairment of these leg movements may be alleviated if the crotch height is increased and if the knee portion of the pant legs (leggings) is made to freely articulate (as was recommended for Commercial A armor).

Commercial C Armor. Subject performance in Commercial C armor was significantly poorer than subject performance in the No Armor control condition on all 15 gross body movements measured. Therefore, it may be stated that the Commercial C suit does not conform with the performance characteristics of the Letter Requirement dealing with body mobility and freedom of head movement. Subject performance in the Commercial C armor does not even approach marginal conformity when compared to the Infantry Armor condition, since subject performance in Commercial C armor was significantly poorer than in Infantry Armor on all but two measures (walking backward and side step) of body mobility. This dramatic inhibition of body movement may be attributed to the large bulk and weight of the suit (see Table 2). While in the Commercial C suit, subjects had extreme difficulty performing trunk flexion, head movements, arm movements, and leg movements. The increased thickness of the suit material, as well as the inclusion of rigid breast and pelvic armor plates, inhibited trunk movements; the thick suit material inhibited arm and leg movements. The weight of the suit hindered rising from a kneeling position. Barring the development of lighter, more flexible armor material from which to fabricate a suit of this design, whole body movement may be increased in this suit if the sleeves were articulated into moveable, flexible joints in the area of the elbow (the knee joints are already articulated) and possibly if a two-piece back apron was fabricated which articulates in the waist area of the back.

Head movements were severely restricted in this suit; head flexion was less than half (47%) of that permitted under the No Armor condition, while head rotation was only 12% of that under the No Armor condition. This inhibition of head movement was basically due to the rigid interface of the helmet (with faceshield) and the high wraparound collar of the armor jacket. When zipped up, the collar was snug against the helmet and the helmet's faceshield was snug against the collar. This helmet-faceshield-collar configuration was so inflexible that the subjects could actually move their heads more than they could move the helmet; that is, if enough effort was exerted, the subject's head would move **within** the helmet but the helmet would not move. Reduction of the collar height and faceshield height may facilitate head movement somewhat. Nevertheless, the basic problem of an inflexible collar would still remain. One possible solution may be the development of an armor collar which is loosely attached to the armor jacket so that it may rotate as the head and helmet rotate; another

possible solution to this problem may be to provide protection to the neck area by attaching a loose armor skirt, or armor bib, to the base of the helmet and faceshield so that head movement may be accomplished without fighting the restriction of an immovable collar.

Commercial D Armor. Subject performance in Commercial D armor was significantly poorer than subject performance in both the No Armor **and** the Infantry Armor control conditions on all 11 indexes of gross body movement measured. Although the design of the Commercial D suit did not permit the measurement of the four upper leg movements, Commercial D armor's extremely poor showing in the three walking movements suggests that Commercial D armor would also demonstrate poor performance on upper leg abduction, forward extension, backward extension, and flexion. As a matter of fact, the Commercial D armor permitted significantly less body mobility than any other armor condition against which it was compared (with the exception of head rotation and upper arm backward extension in the Commercial C armor condition). Consequently, it may be stated without equivocation that Commercial D armor does not conform with the performance characteristics of the Letter Requirement dealing with body mobility and freedom of head movement.

The dramatic inhibition of body movement imposed by the Commercial D suit, even more inhibiting than the Commercial C suit, may be attributed, in general, to its overall bulk, poor flexibility, and extreme weight. While outfitted in the Commercial D suit, subjects had extreme difficulty with trunk flexion, head movements, arm movements, and leg movements. Like the Commercial C suit, trunk movements were inhibited by the thickness of the suit material, as well as the inclusion of rigid breast and pelvic armor plates. However, it is likely that trunk movements were more inhibited in the Commercial D armor because of the addition of an attenuation vest undergarment and a long wraparound apron which extended to below the knee. When subjects attempted to bend at the waist, the hem of the long apron would hit the shins and cause resistance which the subject had to overcome. Since the attenuation vest was extremely flexible, it is likely that only changes in the apron would significantly facilitate trunk flexion. Shortening the apron to above knee level and incorporating an articulating back in the area of the waist would likely facilitate trunk flexion. Arm movements were likely more inhibited in this garment than in the Commercial C garment because the sleeves were directly sewn to the shoulder area without any articulation; in the Commercial C suit, the sleeves were articulated at the arm-shoulder joint and thus provided flexibility for arm movement. Walking movements were largely inhibited by the long armor skirt which prohibited long strides; shortening the skirt to above the knee and making flexible the longitudinal seams at the sides of the coat should alleviate much of this restriction.

Head movements were most severely restricted in this suit; head flexion was 31% of that permitted under the No Armor control condition, while head rotation was less than 10% of that under the No Armor condition. As with the Commercial C armor, this inhibition of head movement was largely due to the rigid interface of the helmet and faceshield with the high wraparound collar. The Commercial C and D helmets were the same. The Commercial D collar was not as tight on the helmet as was the Commercial C collar; however, it was bulkier so that the inability to rotate the head was due more to the bulky collar prohibiting movement of the faceshield than it was due to the tightness of the collar against the helmet shell itself. As suggested with the Commercial C armor, a possible solution to this problem

may be the deletion of the collar and the attachment of an armor bib or skirt to the base of the helmet and faceshield. Such a helmet bib may permit more freedom of head movement.

The influence of sex on performance. Although there were no main effects of the subjects' sex on performance of gross body movements, there were several interactions which showed that the women were generally more encumbered by certain suits than were the men. For example, compared to men, women were more severely hindered by the Commercial C and D armor when performing sitting trunk flexion, standing trunk flexion, and kneel-and-rise. It may be that the overall smaller dimensions of the women (see Table 1) account for this. Since the Commercial C suit and the Commercial D suit were of only one size (large-regular), the women were at a disadvantage in performing these movements. Specifically, the shorter stature of the women allowed the Commercial C and D aprons to hang very close to the floor and thus severely hindered these movements. Women were also more hindered by Commercial A and B suits on head rotation than were the men; observation of the performance of this movement suggested that the faceshield was too long for the women (who were smaller than the men) such that it hit their shoulders during attempts to rotate the head.

In the development of EOD armor for US Army personnel, designers must consider male-female body dimensions in that, at the least, suits of armor must be made to accommodate all personnel (including females who are, in general, smaller than men); and, at the most, suits of armor may have to be specifically designed for the proportions of the male body and for the proportions of the female body. Whether such redesign will be required can only be determined by further research.

II. PSYCHOMOTOR PERFORMANCE AND DONNING/DOFFING INVESTIGATION

Purpose

The purpose in conducting this second investigation of EOD armor was to evaluate finer degrees of body movement than were addressed in the Gross Body Mobility Investigation, to evaluate the speed of donning and doffing the EOD armor, and to evaluate the effect on performance of time in the EOD armor. The performance characteristics addressed in this investigation included: "the total body armor system must — Provide the flexibility necessary for not seriously impeding the wearer" (Letter Requirement, para. 5a(3)), "Be capable of being worn a minimum of one hour" (Letter Requirement, para. 5a(14)), and "Be capable of donning or doffing within five minutes" (Letter Requirement, para. 5a(15)).

Subjects

The twelve subjects, six men and six women, recruited for this investigation are the same subjects who were described in the Introduction section of this report and who participated in the Gross Body Mobility Investigation.

Procedure

Each subject participated in six one-hour test sessions distributed over a period of two days. Subjects were tested in groups of three with the men and the women assigned to separate groups. Two sessions were run each morning or afternoon with a 30-minute rest between sessions; the afternoon of the second day was set aside for make-up if there was a scheduling problem. The subject was administered a different EOD armor condition during each session. The order of presentation of the EOD armor conditions was systematically varied from subject to subject in order that each armor condition was presented first, second, third, fourth, fifth, and sixth at least once for the men and at least once for the women.

During each test session each subject was administered three tests of psychomotor performance (O'Connor Fine Finger Dexterity Task, Cord and Cylinder Manipulation Task, and Pursuit Rotor Task), was timed for speeds of donning and doffing the EOD suit of armor, and was monitored on an index of physical effort (heart rate). During the two days prior to the first test session, each subject received eight daily administrations of each of the psychomotor tasks; the purpose of this practice was to eliminate any confounding effects which may be associated with the learning of these tasks.

With the exception of donning and doffing, each test or measurement was administered twice. The first administration of the three psychomotor tests took approximately 25 minutes and was labeled Period 1. Period 1 was followed by a 15-minute break. The second administration took approximately 20 minutes and was labeled Period 2. The two administrations permitted an evaluation of the possible changes in performance as a function of time in the EOD suit of armor. The tests and measurements utilized in this investigation are described in detail in Appendix C and are briefly described below in the order in which they were administered during each session.

1. **Period 1: Donning.** Each subject was asked to don the EOD suit of armor as quickly as possible. An experimenter assisted the subject in donning each commercial EOD suit of armor; no assistance was provided in either the No Armor or the Infantry Armor conditions. Donning time was measured with a stop clock accurate to 0.01 second. Subjects were tested one at a time.

2. **Period 1: O'Connor Fine Finger Dexterity Task.**[14] In this test of manual dexterity, the subject was required to put three pins in each of 20 holes while using only one hand. Each pin was 1 cm long and 0.1 cm in diameter. This test was administered simultaneously to all three subjects present at the test session. The performance score was the time required to complete the task and was measured on a stop clock accurate to 0.01 second.

3. **Period 1: Cord and Cylinder Manipulation Task.**[15] This was a test of two-handed manual dexterity. It consisted of 10 large loops and one small loop of 0.24 cm woven nylon cord attached at equal intervals to a flexible webbing base with a hook at the far end; and of 10, 1.27 cm plastic cylinders with a 0.95 cm bore. The nearest loop was elongated until the sides were brought together, the doubled end was inserted through a cylinder, and the distal end was opened to form a smaller loop. The next loop was then elongated, passed through the first loop and through a cylinder. This procedure continued until 10 loops formed a chain with one cylinder mounted on each link. The smaller final loop was inserted through the tenth and placed over the hook to complete the task. This test was administered simultaneously to all three subjects present at the test session. The performance score was the time required to complete the task and was measured on a stop clock accurate to 0.01 second.

4. **Period 1: Pursuit Rotor Task.**[16] This standard tracking task involved a high degree of visual-motor coordination. During the test, the subject was required to keep the tip of a hand-held metal stylus on a small moving target. The target consisted of a small flat disc (1.9 cm in diameter) near the edge of a revolving turntable. Contact of the stylus (0.3 cm in diameter) with the target activated a standard digital electric stop clock and provided a measure of performance (time-on-target accurate to 0.01 second). The subject was given four trials on the pursuit rotor, each lasting 30 seconds, with a rest interval of 30 seconds between trials. The turntable revolved at the rate of 60 revolutions perminute. This test was administered to each subject individually. The performance score was the total time-on-target for the four trials (the maximum score was 120 seconds).

[14] Hines, M. and J. O'Connor. A measure of finger dexterity. **Journal of Personnel Research,** 1926, **4**, 379–382.

[15] J. M. McGinnis, J. M. Lockhart, and C. K. Bensel. A human factors evaluation of cold-wet handwear. Technical Report 73–23–PR. Natick, MA: US Army Natick Laboratories, 1972.

[16] See reference 7.

5. **Period 1: Heart Rate.** Immediately after the subject finished the Pursuit Rotor Task, the subject's heart rate (in beats per minute) was measured by means of a digital heart rate monitoring device (Lafayette Instruments, Model 77065). The device consisted of a noninvasive finger clip plethysmograph, which was attached to the subject's right index finger, and a readout module which displayed an updated reading (in beats per minute) with each heart beat. Heart rate was read after the subject had been attached to the monitoring device for 20 seconds.

6. **Interval Between Periods.** At the beginning of this 15-minute interval, the subjects were administered a group hearing test which took approximately eight minutes to administer; this hearing test will be described and reported on in another section of this report. During the remaining time, the subjects were allowed to remain seated and to rest. With the exception of raising their goggles or their helmet's faceshield, the subjects were not allowed to remove any portion of their EOD armor.

7. **Period 2: O'Connor Fine Finger Dexterity Task.** The second administration of this test was conducted at this time.

8. **Period 2: Cord and Cylinder Manipulation Task.** The second administration of this test was conducted at this time.

9. **Period 2: Pursuit Rotor Task.** The second administration of this test was conducted at this time.

10. **Period 2: Doffing.** Each subject was asked, immediately upon completion of the second administration of the pursuit rotor task, to doff the EOD suit of armor as quickly as possible. An experimenter assisted each subject in doffing each commercial EOD suit of armor; no assistance was provided in either the No Armor or the Infantry Armor conditions. Doffing time was measured with a stop clock accurate to 0.01 second.

11. **Period 2: Heart Rate.** Immediately after the subject had doffed the EOD armor, the subject's heart rate was measured.

Results

Sex x Armor x Period analyses of variance were performed on the three measures of psychomotor performance and on heart rate. Sex x Armor analyses of variance were performed on donning time and on doffing time. Summaries of these analyses of variance are presented in Tables 17 through 22. Armor condition had a significant main effect on all these measures. The results of Scheffé tests of multiple comparison performed on the means of these measures are presented in Table 23. There was one significant main effect attributable to sex (doffing time), and one significant interaction between armor and sex (cord and cylinder manipulation). There was one significant main effect attributable to period of testing (pursuit rotor) and one significant interaction between armor and period of testing (pursuit rotor).

Table 17

Summary of Analysis of Variance of
O'Connor Fine Finger Dexterity Task Data

Source of Variation	df	Mean Square	F	p
Sex (G)	1	1987.3	3.07	
Ss/G	10	647.0	–	
Period (P)	1	0.2	<1	
G x P	1	0.6	<1	
Ss x P/G	10	47.1	–	
Armor (E)	5	487.4	5.43	<.001
G x E	5	26.5	<1	
Ss x E/G	50	89.7	–	
P x E	5	49.2	<1	
G x P x E	5	59.3	1.12	
Ss x P x E/G	50	53.2	–	

Table 18

Summary of Analysis of Variance of
Cord and Cylinder Manipulation Task Data

Source of Variation	df	Mean Square	F	p
Sex (G)	1	277.6	<1	
Ss/G	10	295.0	–	
Period (P)	1	0.9	<1	
G x P	1	0.5	<1	
Ss x P/G	10	34.0	–	
Armor (E)	5	639.9	18.03	<.001
G x E	5	196.6	5.54	<.001
Ss x E/G	50	35.5	–	
P x E	5	19.6	<1	
G x P x E	5	10.1	<1	
Ss x P x E/G	50	24.3	–	

Table 19

Summary of Analysis of Variance of
Pursuit Rotor Task Data

Source of Variation	df	Mean Square	F	p
Sex (G)	1	328.4	<1	
Ss/G	10	1245.7	–	
Period (P)	1	2313.7	74.42	<.001
G x P	1	71.8	2.31	
Ss x P/G	10	31.1	–	
Armor (E)	5	4244.5	20.13	<.001
G x E	5	174.5	<1	
Ss x E/G	50	210.9	–	
P x E	5	129.2	4.00	<.01
G x P x E	5	47.9	1.48	
Ss x P x E/G	50	32.3	–	

Table 20

Summary of Analysis of Variance of
Donning Time Data

Source of Variation	df	Mean Square	F	p
Sex (G)	1	3071.3	3.85	
Ss/G	10	797.7	–	
Armor (E)	5	89326.1	113.08	<.001
G x E	5	456.2	<1	
Ss x E/G	50	789.9	–	

Table 21

Summary of Analysis of Variance of
Doffing Time Data

Source of Variation	df	Mean Square	F	p
Sex (G)	1	1153.8	17.07	<.01
Ss/G	10	67.6	–	
Armor (E)	5	5960.0	88.24	<.001
G x E	5	87.8	1.30	
Ss x E/G	50	67.5	–	

Table 22

Summary of Analysis of Variance of Heart Rate Data

Source of Variation	df	Mean Square	F	p
Sex (G)	1	47.8	<1	
Ss/G	10	508.8	–	
Period (P)	1	41.2	<1	
G x P	1	10.6	<1	
Ss x P/G	10	62.1	–	
Armor (E)	5	486.6	4.70	<.01
G x E	5	231.3	2.2	
Ss x E/G	50	103.6	–	
P x E	5	41.6	<1	
G x P x E	5	29.5	<1	
Ss x P x E/G	50	59.1	–	

Table 23

Mean Scores for Psychomotor Tasks, Donning/Doffing, and Heart Rate

Measure	Armor Condition					
	No Armor	Infantry Armor	Commercial EOD Armor A	B	C	D
O'Connor Fine Finger Dexterity Task (sec.)	71.60	76.05	80.94	78.70	81.63	84.23
Cord & Cylinder Manipulation Task (sec.)	43.30	43.23	47.89	43.74	50.01	56.27
Pursuit Rotor Task (sec.)	103.27	101.12	89.56	88.39	75.14	70.37
Time to Don (sec.)	0.00	25.10	92.41	103.03	205.25	203.00
Time to Doff (sec.)	0.00	8.76	24.05	26.44	62.46	39.47
Heart Rate (beats/min.)	67.3	66.8	68.5	70.2	75.2	77.8

Note: Armor conditions not connected by the same line are significantly different from one another ($p<.05$). Armor conditions above the dotted portion of a line are not to be considered affected by that line; for example, for the Cord & Cylinder Task, performance in "C" armor is significantly different from every other armor condition except "A" armor.

O'Connor Fine Finger Dexterity Task. Compared to the No Armor control condition, subjects scored significantly poorer on this task when outfitted in Commercial C or D armor. When outfitted in either Commercial A or B armor, their performance did not differ from either the No Armor condition or the Infantry Armor condition. The relationships between all the armor means are presented in detail in Table 23 and are represented graphically in Figure 38. There were no statistically significant differences between the performances of men and women on this task; neither were there any significant differences in performance exhibited by the subjects between the first and second administration of this task (that is, between Periods 1 and 2).

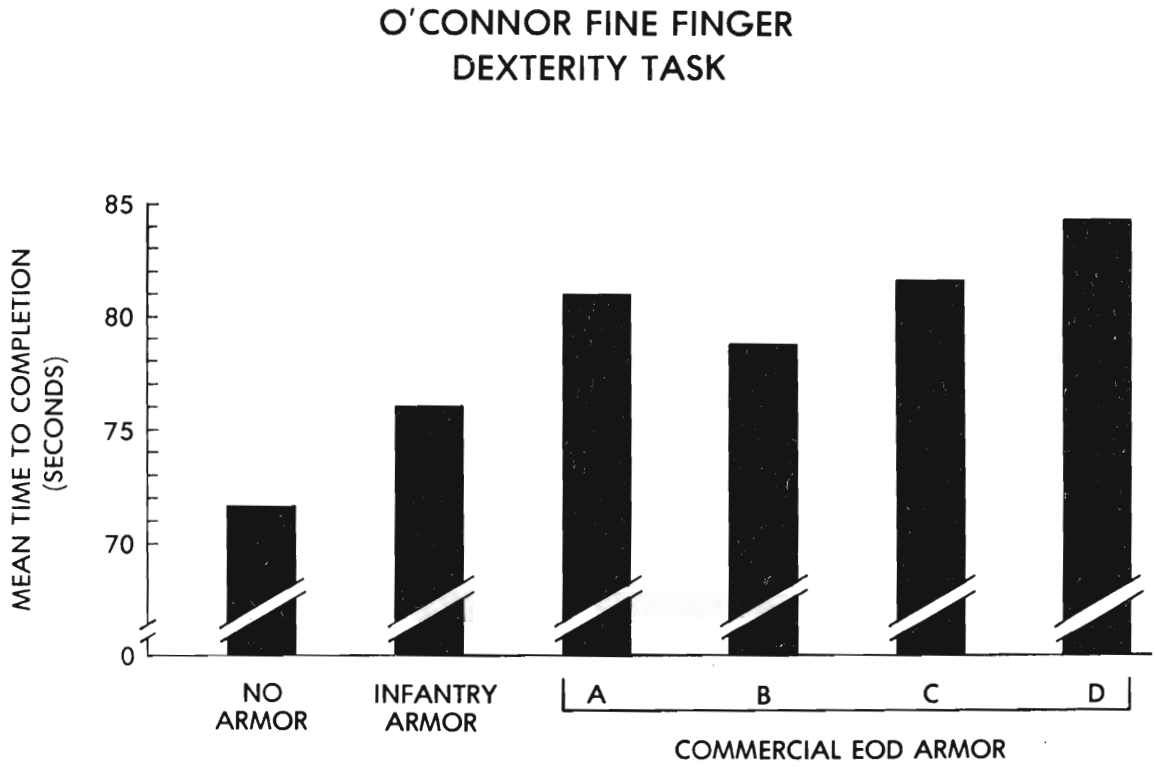

Figure 38. **Mean Score on O'Connor Fine Finger Dexterity Task as a Function of Armor Condition.**

Cord and Cylinder Manipulation Task. The subjects took longer to complete the cord and cylinder manipulation task when in the Commercial D armor than they did in any other condition. When in Commercial C armor, subjects' performances were significantly slower than in either of the control conditions. Performance in Commercial A and B armor was not significantly slower than in the control conditions. The relationships between the armor means on this task are presented in detail in Table 23. There was no significant difference in performance on this task between Period 1 and Period 2. However, there was a significant armor x sex interaction such that, within every armor condition, except Commercial D armor, the difference between the men's scores and the women's scores was nonsignificant; in the Commercial D armor condition, the women took significantly longer than the men to complete the task (63.26 seconds as opposed to 49.28 seconds). These relationships are graphically presented in Figure 39.

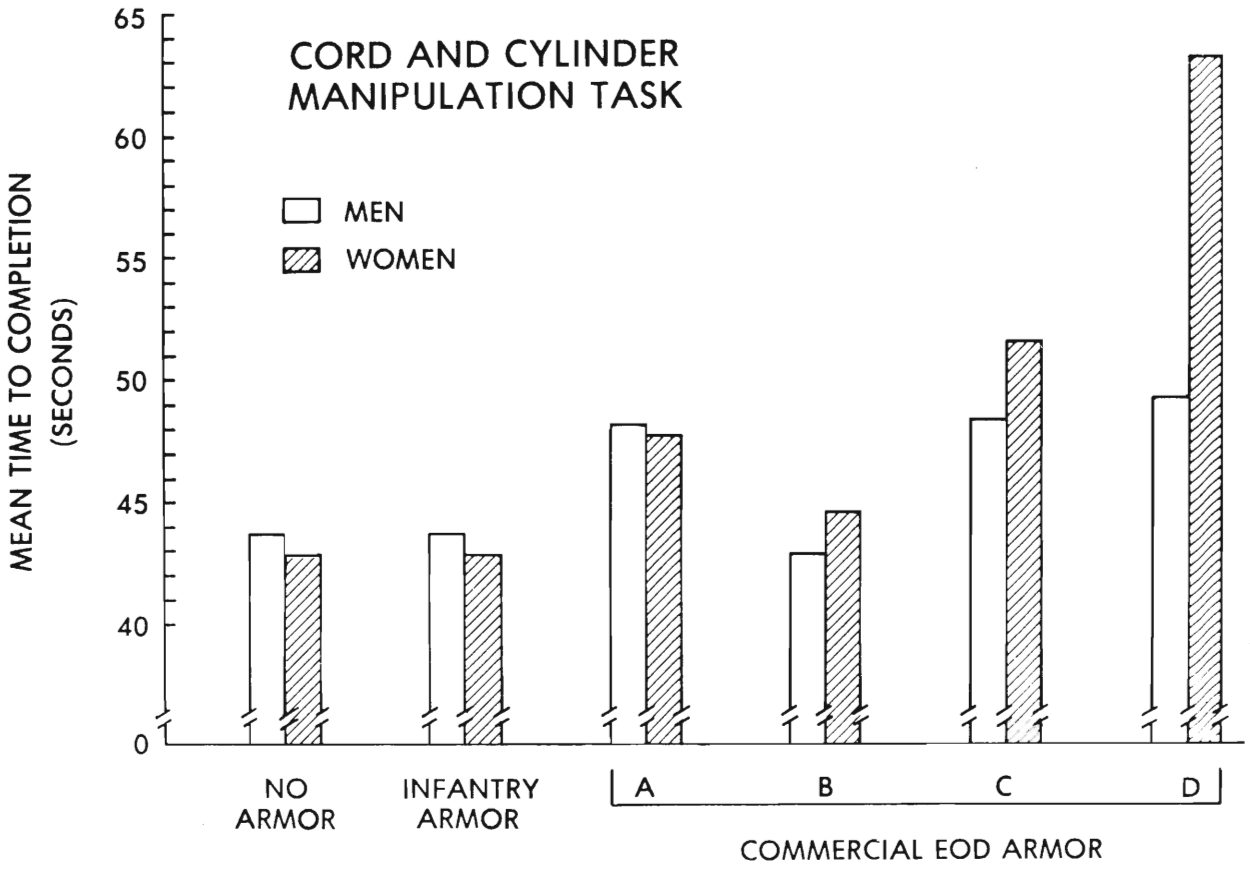

Figure 39. Mean Score on Cord and Cylinder Manipulation Task as a Function of Armor Condition and Sex.

Pursuit Rotor Task. The subjects obtained significantly less time-on-target when in the Commercial C and D armor conditions than they did in any other condition. When in Commercial B armor, the subjects obtained significantly less time-on-target than they did in the No Armor control condition. Performance in Commercial A armor did not differ from either the No Armor condition or the Infantry Armor condition on this task. The relationships between the armor means on the pursuit rotor task are presented in detail in Table 23. There was no significant main effect for sex. However, there was a significant main effect for period of test administration such that the overall mean score for Period 2 (91.98 seconds) was significantly higher than the overall mean score for Period 1 (83.97 seconds). A significant armor x period interaction showed that, within every armor condition except Commercial C and D armor conditions, the difference between Period 1 and Period 2 mean scores was nonsignificant; in the Commercial C and D armor conditions, the Period 1 mean scores were significantly lower (67.58 and 64.46 seconds for Commercial C and D armor, respectively) than the Period 2 mean scores (82.70 and 76.28 seconds for Commercial C and D armor, respectively). These relationships are graphically represented in Figure 40.

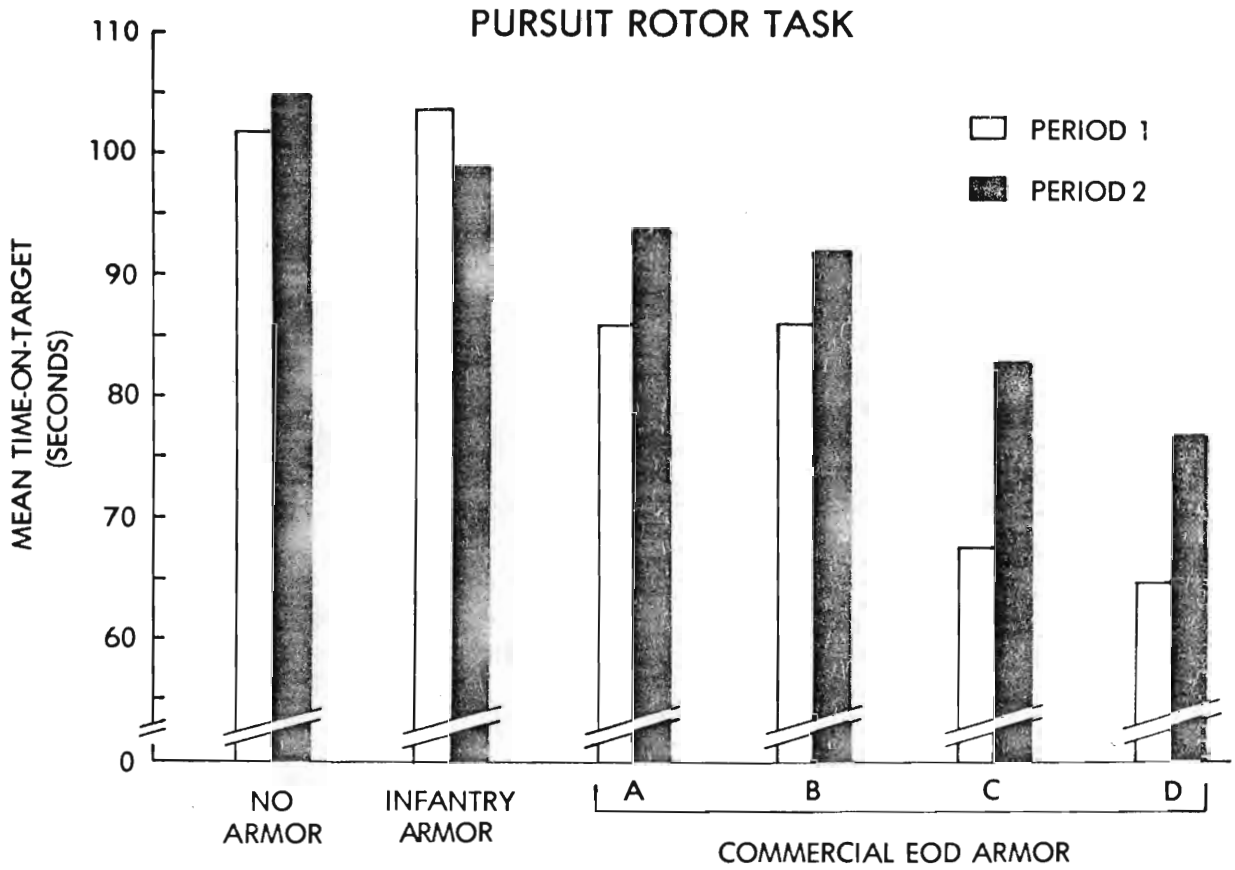

Figure 40. Mean Score on Pursuit Rotor Task as a Function of Armor Condition and Period of Testing.

Donning. The subjects took significantly more time to don the Commercial C and D suits of armor than they did to don any other suit of armor. When the subjects donned either Commercial A armor or Commercial B armor, they took significantly more time than either control condition but significantly less time than either Commercial C or D conditions. The relationships between the mean scores for donning are presented in detail in Table 23 and are graphically represented in Figure 41. Speed in donning did not differ between male and female subjects.

Doffing. The subjects took significantly more time to doff the Commercial C armor than they did to doff any other suit of armor. Subjects took significantly less time to doff the Commercial D armor than they did to doff Commercial C armor, but the Commercial D armor took significantly more time to doff than did any of the remaining conditions. Commercial A and B armor took significantly more time to doff than did the Infantry Armor or No Armor. The relationships between armor mean scores are presented in detail in Table 23. In addition, there was a significant main effect for sex such that, in general, women took more time (mean = 30.87 seconds) to doff their suits of armor than did the men (mean = 22.86 seconds). These relationships are graphically represented in Figure 42.

Heart Rate. Mean heart rate was higher in the Commercial D armor condition than it was in either of the control conditions. Mean heart rates were not significantly different among any of the other conditions. The relationships between the armor mean heart rates are presented in detail in Table 23 and are represented graphically in Figure 43. There were no significant differences in this measurement either between men and women or between Period 1 and Period 2 measurements.

Discussion

Since there is no standard Army EOD armor with which to compare the four commercial EOD suits, the No Armor and the Infantry Armor control conditions were included. The following will be used as guidelines for discussion of the four commercial EOD suits.

1. If, with respect to psychomotor performance, subject performance in a particular commercial EOD suit does not differ from subject performance in the No Armor control condition, **it may be stated that the suit conforms with the relevant performance characteristic of the Letter Requirement** (namely, paragraphs 5a(3), and 5a(14)).

2. If, with respect to psychomotor performance, subject performance in a particular commercial EOD suit is not as good as in the No Armor control condition, but is as good as (or better than) performance in the Infantry Armor control condition, **it may be stated that the suit marginally conforms with the relevant performance characteristics of the Letter Requirement** (namely, paragraphs 5a(3), and 5a(14)).

3. If a particular commercial EOD suit can be donned or doffed within five minutes, **it may be stated that the suit does not conform with the relevant performance characteristic of the Letter Requirement** (namely, paragraph 5a(15)).

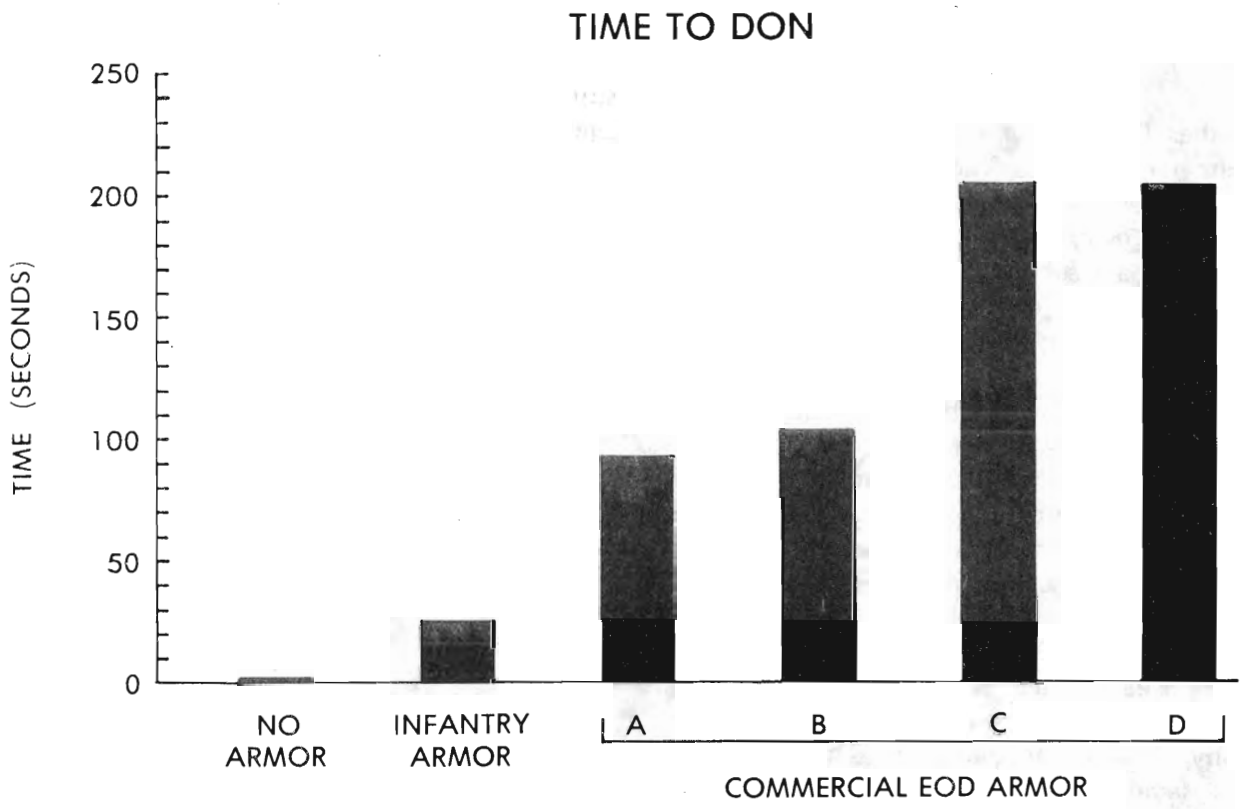

Figure 41. Mean Time to Don as a Function of Armor Condition.

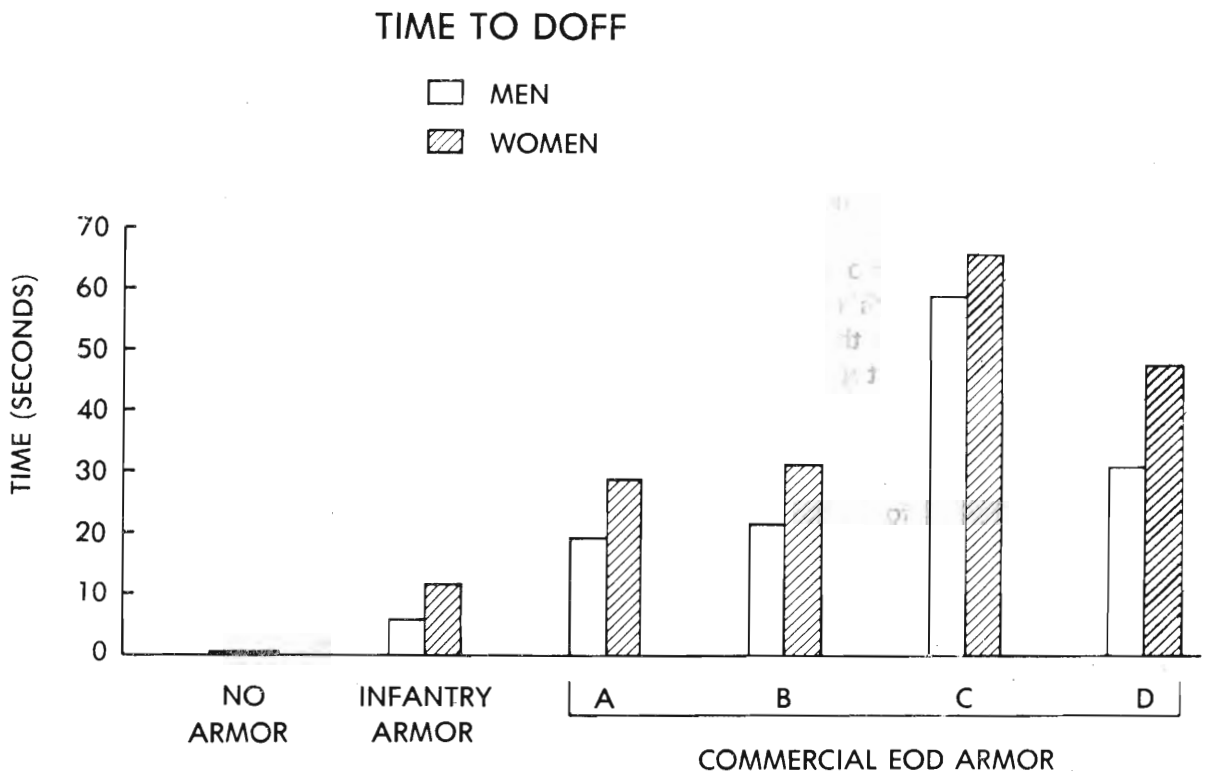

Figure 42. Mean Time to Doff as a Function of Armor Condition and Sex.

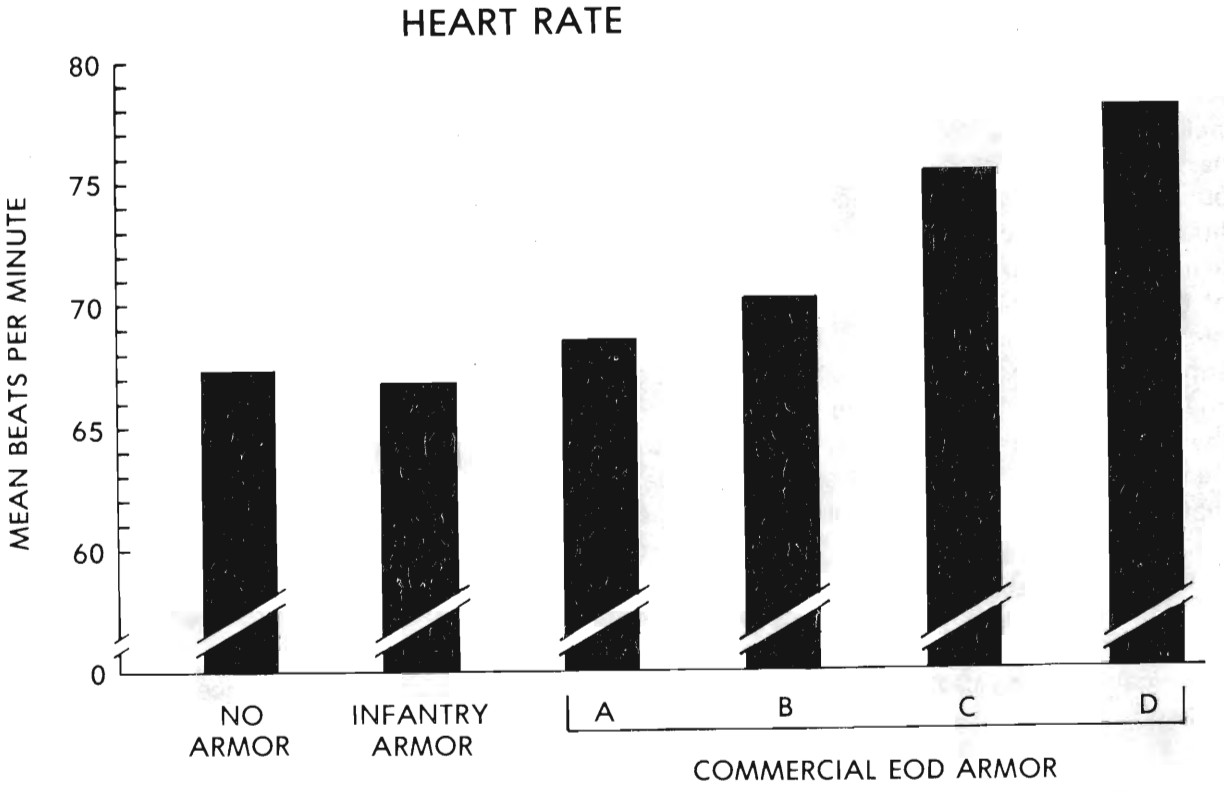

Figure 43. Mean Heart Rate as a Function of Armor Condition.

Each of the four commercial EOD suits is discussed below in comparison with the No Armor and the Infantry Armor control conditions.

Commercial A armor. The three psychomotor tasks utilized in this investigation included one one-handed task (fine finger dexterity), one two-handed task (cord and cylinder manipulation), and one task involving the simultaneous use of the hand, arm, and shoulder (pursuit rotor). With respect to these three psychomotor tasks, subject performance in Commercial A armor was not significantly different from subject performance in the No Armor control condition. Therefore, it may be stated that Commercial A armor conforms with the performance characteristic dealing with flexibility (para. 5a(3) of the Letter Requirement). In addition, since subject performance did not deteriorate between the first and the second administrations of these tasks, it may be stated that Commercial A armor conforms with the performance characteristic dealing with the capability of "being worn one hour" (para. 5a(14) of the Letter Requirement). Although Commercial A armor took longer to don and to doff than the Infantry Armor, it conforms with the performance characteristic dealing with donning/doffing (para. 5a(15) of the Letter Requirement) since the suit of armor was capable of being donned or doffed within the prescribed five minutes. The heart rate data indicated that, while in Commercial A armor, the subjects exerted no more physical effort than they did in the No Armor control condition over the course of the hour of testing. In sum, all the data of Investigation II indicate that the Commercial A armor conforms with the performance characteristics addressed in the investigation.

Commercial B armor. With respect to the three psychomotor tasks, it may be stated that, while in Commercial B armor, subjects performed just as well as in the No Armor condition on two of the tasks (fine finger dexterity and cord and cylinder manipulation) and not as well on the third task (pursuit rotor). The decrement in pursuit rotor performance may have been due to the increased weight of the armor vest. Nevertheless, with respect to the pursuit rotor task, subjects performed as well in the Commercial B armor as they did in the Infantry Armor condition. Therefore, it may be stated that, in general, Commercial B armor marginally conforms with the performance characteristic dealing with flexibility (para. 5a(3) of the Letter Requirement). In addition, since subject performance did not deteriorate between the first and the second administrations of these tasks, it may be stated that Commercial B armor conforms with the performance characteristic dealing with the capability of "being worn one hour" (para. 5a(14) of the Letter Requirement). Commercial B armor also conforms with the performance characteristic dealing with donning/doffing (para. 5a(15) of the Letter Requirement) since the suit of armor was capable of being donned or doffed within five minutes; that it took longer to don or doff the Commercial B armor than it did to don or doff Infantry Armor was obviously due to the greater number of components of the Commercial B suit of armor. The heart rate data indicate that while in Commercial B armor the subjects exerted no more physical effort than they did in the No Armor control condition over the course of the hour of testing. In sum, with the exception of the pursuit rotor data, the data of Investigation II indicate that Commercial B armor conforms with the performance characteristics addressed in the investigation.

Commercial C armor. With respect to the three psychomotor tasks, it may be stated that while in Commercial C armor subjects performed just as well as in the No Armor condition on only one of the tasks (fine finger dexterity) and not as well on the other two tasks (cord and cylinder manipulation, and pursuit rotor). While in Commercial C armor, subjects did not do as well on the latter two tasks as in the Infantry armor condition. Therefore, it may be stated that, in general, Commercial C armor does not conform with the performance characteristic dealing with flexibility (para. 5a(3) of the Letter Requirement).

This demonstrated inferiority of the Commercial C suit of armor during psychomotor performance was most likely due to the large bulk and stiffness in the arm and shoulder areas of the suit. Shoulder flexibility is most important in the cord and cylinder manipulation task since, in this two-handed task, the subject must bring both hands together in front of the body (during the O'Connor task, only one hand need be placed in front of the body). In Investigation I on gross body mobility, it was found that upper arm forward extension was next to the poorest in the Commercial C armor condition. Therefore, it is consistent with the Investigation I results that the subjects performed significantly poorer in the Commercial C armor condition than in both control conditions on the cord and cylinder manipulation task. It is possible that flexibility in the arm and shoulder area of the Commercial C suit of armor may be increased by reducing the thickness of the armor material at the arm-shoulder joint.

In addition, since subject performance did not deteriorate between the first and the second administrations of these tasks, it may be stated that Commercial C armor conforms with the performance characteristic dealing with the capability of "being worn an hour" (para. 5a(14) of the Letter Requirement). That performance on the pursuit rotor actually improved from Period 1 to Period 2 suggests that an EOD technician should be encouraged to train in the Commercial C armor in order to perform at his best when on an actual mission.

Commercial C armor also conforms with the performance characteristic dealing with donning/doffing (para. 5a(15) of the Letter Requirement) since the suit of armor was capable of being donned or doffed within the prescribed five minutes; that it took subjects wearing the Commercial C armor longest to doff this suit as compared to any of the other suits indicates that a quick-release feature is desirable (that such a quick-release feature was incorporated into the bulkiest of the suits suggests that it could also be incorporated into the Commercial C suit of armor). The heart rate data indicate that while in Commercial C armor the subjects exerted no more physical effort than they did in the No Armor control condition over the hour of testing.

In sum the data of Investigation II indicate that Commercial C armor (1) conforms with two of the performance characteristics (donning/doffing and capability of being worn one hour) of the Letter Requirement and (2) does not conform with one of the performance characteristics (flexibility) of the Letter Requirement.

Commercial D armor. With respect to the three psychomotor tasks, it may be stated that while in Commercial D armor subjects did not perform as well as in the No Armor control condition. On only one task (fine finger dexterity) did subjects perform as well as in the Infantry Armor condition. Therefore, it may be stated that Commercial D armor does not conform with the performance characteristic dealing with flexibility (para. 5a(3) of the Letter Requirement). As with Commercial C armor, this demonstrated inferiority of the Commercial D suit of armor during psychomotor performance was most likely due to the large bulk and stiffness in the arm and shoulder areas of the suit. In Investigation I, it was found that upper arm forward extension was poorest in the Commercial D armor condition; it is consistent that the subjects performed significantly poorer in the Commercial D armor condition than in all the other armor conditions (including the Commercial C armor condition) on the cord and cylinder manipulation task. It is possible that flexibility in the arm-shoulder area of the Commercial D suit may be increased by (1) not sewing the sleeves directly to the shoulder area, but rather by articulating the arm-shoulder joint as is the case with the Commercial C suit, and (2) decreasing the thickness of the armor material in the area of the arm-shoulder joint. In addition, since subject performance did not deteriorate between the first and the second administrations of the tasks, it may be stated that Commercial D armor conforms with the performance characteristic dealing with the capability of "being worn one hour" (para. 5a(14) of the Letter Requirement). That performance on the pursuit rotor actually improved from Period 1 to Period 2 suggests that an EOD technician should be encouraged to train in the Commercial D armor in order to perform at his best when on an actual EOD mission.

Commercial D armor also conforms with the performance characteristic dealing with donning/doffing (para. 5a(15) of the Letter Requirement) since it was capable of being donned or doffed within the prescribed five minutes; a quick-release feature permitted this garment to be doffed significantly more rapidly than the Commercial C suit and thus is a desirable feature.

The heart rate data indicate that heart rate was higher in the Commercial D suit of armor than in either of the two control conditions. This finding suggests that the wearer had to exert much physical effort in this suit of armor. This finding may be due to the fact that the Commercial D suit of armor was the heaviest (60.19 lbs.) of those tested.

In sum, the data of Investigation II indicate that Commercial D armor conforms with two of the performance characteristics (donning/doffing, and capability of being worn one hour) of the Letter Requirement and (2) does not conform with one of the performance characteristics (flexibility) of the Letter Requirement.

The influence of sex on performance. There was one significant main effect for sex such that, regardless of the type of EOD armor being doffed, women consistently took longer to doff their suits of armor than did the men. Observation of the doffing procedure, as well as examination of the objective data, suggested no reason for this difference. Observations did not suggest that women had difficulties in doffing that were unique to them. The women simply appeared to be less concerned with doffing speed than did the men; their movements were not as vigorous as the men's movements. However, as compared to the male subjects, the women appeared to rely more on the experimenter (a male) to assist them in doffing each garment. Therefore, this statistically significant difference between men and women in doffing **may** be a reflection of (1) a difference in magnitude of motivation between men and women on this task, (2) cultural expectation (women are "supposed" to let men assist them with difficult tasks), or (3) a combination of these two factors. Only further research can aid in correctly interpreting this result.

The data also showed that women took significantly longer than the men to complete the cord and cylinder manipulation task while in the Commercial D armor. This finding is likely due to the smaller build of the women and to the fact that the Commercial D armor came in only one size, large-regular. The fact that this relationship did not hold for the other suits of armor (including the Commercial C suit of armor which also came in only size, large-regular) demonstrates the considerable encumbering effects of the Commercial D arm-shoulder design.

III. SPEECH INTELLIGIBILITY INVESTIGATION

Purpose

The purpose in conducting this investigation was to determine to what extent the wearer of EOD armor could hear speech and to what extent the wearer's speech could be heard. The performance characteristics addressed in this investigation were: "the total body armor system must – Not impede – hearing of the wearer with respect to accomplishment of the mission" (Letter Requirement, para. 5a(4)) and "the total body armor system must – Not prevent talk to a degree that would seriously affect the accomplishment of the mission" (Letter Requirement, para. 5a(16)).

Subjects

The twelve subjects, six men and six women, recruited for this investigation are the same subjects who were described in the Introduction section of this report and who participated in Investigations I and II of this report.

Procedure

In order to assess the hearing of subjects clothed in EOD armor, an objective test designed to evaluate the ability to correctly identify spoken words (the Modified Rhyme Test)[17] was administered to the subjects while they were appropriately clothed for each of the six EOD armor conditions. In order to assess the ability of the wearer of EOD armor to be heard while speaking, subjects were again administered this same test for each of the six armor conditions; this time, however, the experimenter administered the test while separately wearing each of the six suits of armor and the test subjects were bareheaded. These procedures are briefly described below. The Modified Rhyme Test materials are reproduced in Appendix D.

1. Hearing: Modified Rhyme Test. This group hearing test was administered during the 15-minute interval between Periods 1 and 2 of the Psychomotor Performance and Donning/Doffing Investigation (Investigation II of this report). The order of presentation of the EOD armor conditions was therefore the same as in Investigation II. The administration of the test took approximately eight minutes each time it was presented, and was presented six times, once for each EOD Armor condition. Testing of the six conditions was distributed over a period of two days. In the three days prior to the test sessions, all subjects received six practice administrations of the test while in a bare-headed condition. During these practice sessions, subjects were exposed to all stimuli (test words) that would be used during the test sessions. During each test session, each subject was administered the Modified Rhyme Test.

[17] A. S. House, C. E. Williams, M. H. L. Hecker, and K. D. Kryter. Articulation testing methods: consonantal differentiation with a closed response set. **Journal of the Acoustical Society of America, 37**, 158–166, 1965.

This test consisted of six equivalent word lists (50 monosyllabic words per list). For each stimulus word spoken to the subject, the subject had available a closed set of six alternatives from which the subject was required to identify the message. Any cluster of six alternatives was characterized by one vowel that was the nucleus of each word. All the words in a given cluster were either initiated or terminated by the same consonant phoneme (for example, pass, pat, pack, pad, path, pan). The subject was presented one word every five seconds until the word list was exhausted. The test room utilized in this study had a constant ambient background noise, the fan of an air conditioning unit (the compressor was located in a separate room). The word list was presented by means of a tape recorder set at the same volume level each time the list was presented. The volume level selected was based upon pilot work which demonstrated that subjects in a bareheaded condition could hear and correctly identify no less than 41, but no more than 48 of the 50 words presented; the pilot work was conducted in the same test room with the same ambient noise as was the case during the actual test sessions. The subject's performance score was the percent of words correctly identified.

2. **Speech Communication: Modified Rhyme Test.** This test was administered two days after the administration of the hearing test. In order to determine the relative extent to which the wearing of EOD armor may impair the ability of the wearer to be heard when speaking, the Modified Rhyme Test was again administered to each test subject under each of the six EOD armor conditions. This time, however, the talker (an experimenter) administered the test while separately wearing each of the six EOD suits of armor. The test subjects were bareheaded and listened for the stimulus words spoken by the experimenter. The word lists were the same as those used during the hearing test, but the order of presentation of the lists varied. The administration of all six tests for all six EOD conditions was conducted on one day. Subjects received a 15-minute rest between each administration of the test. The experimenter attempted to maintain the same speech volume level for each armor condition by monitoring a V.U. meter during extensive practice. The ability to communicate by speech while the talker was assuming one of the armor conditions was measured by the percent of words correctly identified by the test subjects.

Results

Sex x Armor analyses of variance were conducted on the performance scores for the hearing test and on the performance scores for the speech communication test. Summaries of these analyses of variance are presented in Tables 24 and 25.

1. **Hearing: Modified Rhyme Test.** Armor condition had no significant effect on hearing as measured by the Modified Rhyme Test. The ability to identify spoken words correctly was the same whether the subjects wore no armor or donned EOD armor. There was no significant difference between the men's and the women's ability to hear speech. The precise mean scores for the various armor conditions are presented in Table 26 and are graphically displayed in Figure 44.

Table 24

Summary of Analysis of Variance of
Hearing (Modified Rhyme Test) Data

Source of Variation	df	Mean Square	F	p*
Sex (G)	1	60.5	<1	
Ss/G	10	84.4	–	
Armor (E)	5	73.4	2.16	
G x E	5	74.4	2.19	
Ss x E/G	50	33.9	–	

*None significant at $\alpha = .05$.

Table 25

Summary of Analysis of Variance of
Speech Communication (Modified Rhyme Test) Data

Source of Variation	df	Mean Square	F	p
Sex (G)	1	227.6	1.25	
Ss/G	10	182.4	–	
Armor (E)	5	2139.4	41.00	<.001
G x E	5	55.8	1.07	
Ss x E/G	50	52.2	–	

Table 26

Mean Scores for Hearing and Speech Communication

Measure	Armor Condition					
	No Armor	Infantry Armor	Commercial EOD Armor			
			A	B	C	D
Hearing (per cent correct on Mod. Rhyme Test)	85.8	81.3	83.7	84.0	81.0	79.0
Speech Communication (per cent correct on Mod. Rhyme Test)	89.7	90.3	75.8	76.2	60.2	60.2

NOTE: Armor conditions not connected by the same line are significantly different from one another ($<.05$).

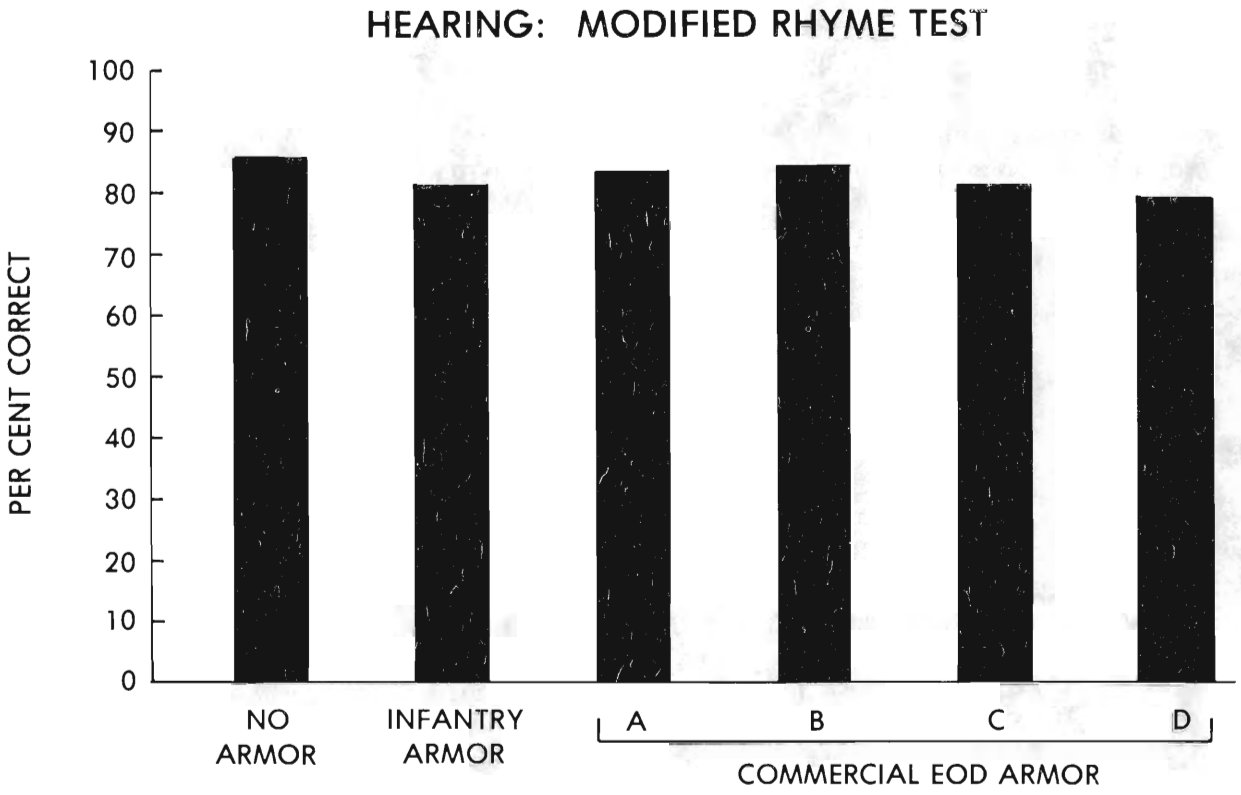

Figure 44. Mean Score on Hearing (Modified Rhyme Test) as a Function of Armor Condition.

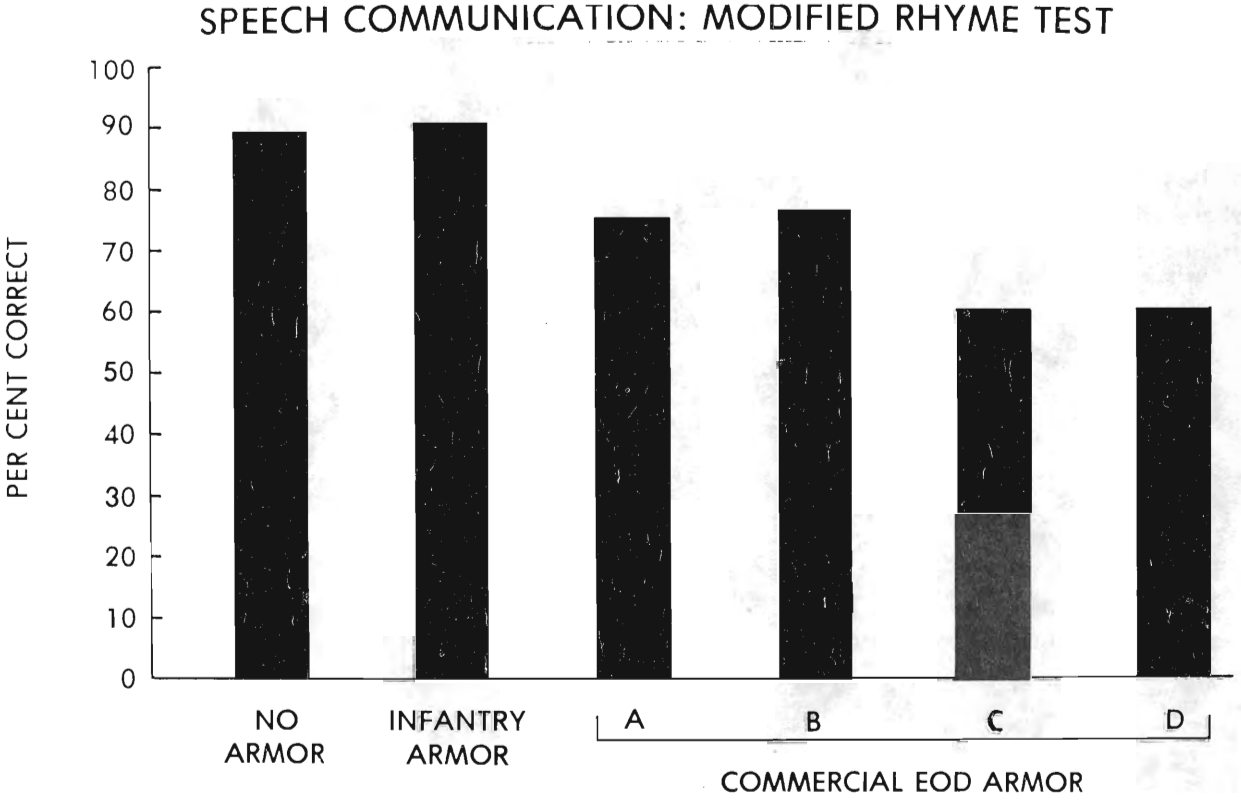

Figure 45. Mean Score on Speech Communication (Modified Rhyme Test) as a Function of Armor Condition.

2. **Speech Communication: Modified Rhyme Test.** Armor had a significant effect on speech communication as measured by the Modified Rhyme Test. As compared to the No Armor and the Infantry Armor control conditions, the ability to be heard while speaking was significantly poorer when the speaker was wearing either the Commercial C or the Commercial D armor. As compared to the No Armor and the Infantry Armor control conditions, the ability to be heard while speaking was also significantly impaired by the speaker wearing of the Commercial A or B armor; however, the ability to be heard while the speaker was wearing either the Commercial A or B armor was significantly better than that under either the Commercial C or D armor conditions. There were no other significant effects. The relationships between the armor means are presented in detail in Table 26 and are graphically presented in Figure 45.

Discussion

The results of this investigation indicate that individuals could hear speech just as well whether they were wearing EOD armor or not. Since there were no ear coverings incorporated into the Commercial A and B armor, this was not an unusual finding. On the other hand, the Commercial C and D armor systems incorporated a helmet which included tight fitting earphones. The earphones had the capability, by means of mechanical levers, to be placed in an "open" position to permit the wearer to hear ambient sound. For this test, the levers were placed in the "open" position. It is clear that setting the Commercial C and D earphones in the "open" position permitted the wearer to hear speech just as well as when the wearer was wearing no earphones at all. Since none of the EOD suits of armor impeded the hearing of speech, all the EOD suits of armor conform with that performance characteristic of the Letter Requirement pertaining to hearing (para. 5a(4)).

The results of this investigation also indicate that the extent to which one's speech could be heard was impaired by the donning of EOD armor by the speaker. Under the two control conditions (No Armor and Infantry Armor), subjects could correctly identify aproximately 90% of the words spoken by the experimenter. According to MIL–STD–1472B, this level of hearing of isolated words (i.e., mean score on the Modified Rhyme Test) means that about 98% of spoken sentences will be heard and that this is normally acceptable speech intelligibility.[18] Under Commercial A and B armor conditions, approximately 75% of the speaker's words could be correctly identified; according to MIL–STD–1472B, this means that about 90% of spoken sentences will be heard correctly and that this level of speech intelligibility is minimally acceptable. This deterioration in speech intelligibility may be attributed to the faceshields of Commercial A and B suits or armor, since no faceshields were worn in the two control conditions.

[18]Military Standard, MIL–STD–1472B. Human Engineering Design Criteria for Military Systems, Equipment and Facilities, Washington, D.C.: Department of Defense, 1974.

Under the Commercial C and D armor conditions, approximately 60% of the speaker's words could be correctly identified by the bareheaded subjects; according to MIL–STD–1472B, this means that less than 90% of spoken sentences will be heard correctly and that this level of speech intelligibility is unacceptable. This severe deterioration in speech intelligibility may be attributed to the faceshield and high collar combination of the Commercial C and D suits of armor. Designers of future EOD suits of armor must develop suit characteristics which will permit better levels of speech intelligibility than were measured under the EOD armor conditions of this investigation. Speech communication may be improved somewhat in the Commercial C and D suits by means of reducing the size of the overlap of the collar with the faceshield. Speech communication may also be improved by means of electrical aids such as radio or wire communications. Both Commercial C and D suits are designed to permit electrically-aided communication as an option; Commercial A and B suits do not easily permit such an option.

IV. VISUAL FIELD INVESTIGATION

Purpose

The purpose in conducting this investigation was to determine the limits of the visual field of subjects outfitted in EOD armor and to compare these limits to those limits of the visual field when no armor is worn. The performance characteristic addressed in this investigation was: "the total body armor system must -- Not impede vision -- of the wearer" (Letter Requirement, para. 5a(4)).

Subjects

The twelve subjects, six men and six women, recruited for this investigation, are the same subjects described in the Introduction section of this report and who participated in Investigations I, II, and III of this report.

Procedure

Measurements of the visual field were made on each subject while wearing the appropriate headgear (helmet with faceshield or goggles) for each EOD armor condition. Subjects were tested individually on all six EOD armor conditions during the course of one day: three conditions in the morning and three conditions in the afternoon. The measurement of the visual field of each EOD condition took approximately 20 minutes with a ten minute rest between conditions. The break between the morning and afternoon test sessions was a minimum two hours. The order of presentation of EOD armor conditions was systematically varied from subject to subject in order that each armor condition was presented first, second, third, fourth, fifth, and sixth at least once for the men and at least once for the women. Measurements of the visual field were made on a Bausch and Lomb projection perimeter (Cat. No. 71-77-50) under a fixated eye condition (see Figure E1 in Appendix E). The subject fixated one eye on an illuminated cross-slit in the center of the visual field and continued to fixate on this cross-slit during the perimetric measurement. The other eye was blindfolded. The subject's task was alternately to detect an illuminated target moving in from the periphery or to detect the disappearance of the target as it moved toward the periphery. The target to be detected was a white circular dot with a diameter of 5 mm which subtended a visual angle of 0.9°. The measurements were made monocularly for each eye for each of the eight areas of the visual field: nasal, super-nasal, superior, super-temporal, temporal, infero-temporal, inferior, and infero-nasal. For each of the areas of the visual field the limit of the area was measured twice: once with the target moving in from the periphery and once with the target moving toward the periphery. The arithmetic mean of these two measurements was treated as the limit of that area of the visual field for that eye.

The visual field of each subject was measured in this manner under each of the six armor conditions, and, as was stated earlier, only the headgear items for each armor condition were worn during measurement. There were two exceptions, however. When the inferior portion of the visual field was measured under the Commercial C and D armor conditions, the subject was dressed in the full suit of armor. This was done because the Commercial C and D armor had high collars which came in front of the face and which likely interfered with the inferior field of view. Since it was impossible for the subject's head to be placed in the Bausch and Lomb perimeter when the collar was worn, the inferior limit had to be determined by different means. While in the full suit of armor, the subject sat facing a wall. On the wall was a fixation point at eye level. The subject was positioned so that his eye was one meter from the wall. A circular dot 15 mm in diameter was moved in from (and out of) the inferior periphery with the subject reporting detection (or disappearance) just as in the Bausch and Lomb perimetry situation. The 15 mm dot was selected since, at one meter, it subtended a visual angle of 0.9°, the same as in the formal perimetry situation. The distance between the fixation point on the wall and the detection point in the inferior field of view was taken as the raw score. Given that the figure described by a line drawn from the eye, to the fixation point, to the detection point, and back to the eye was a right triangle, the inferior limit of the field of view (in degrees angle) was calculated as follows: (a) the distance from the fixation point to the detection point was divided by the distance from the eye to the fixation point; (b) the answer to step (a) was the tangent of the angle formed between the line of sight to the fixation point and the line of sight to the detection point; and (c) the inferior limit of the field of view was then read directly from a table of trigonometric functions by finding what angle was associated with a tangent of that value.

Results and Discussion

Figures 46 through 51 are plots of the mean visual fields for men and for women under each of the six armor conditions. For each sex, the measurements from the right and left eye were combined (reversing portions of the visual field for the left eye as required) to obtain one mean value for each of the eight areas of the visual field. By inspection of these figures, it can be seen that, within each armor condition, there was no appreciable difference between men's and women's visual fields. In view of this, the men's and the women's data were combined for each armor condition and the resultant visual fields are presented in Figure 52.

Inspection of Figure 52 shows that the largest visual field was obtained in the No Armor condition. The Infantry Armor condition drastically reduced the visual field in all eight areas; this may be attributed to the CVC goggles which fit closely about the area of the eyes. Commercial A and B armor reduced the visual field, compared to the No Armor Control, mainly in the super-nasal, superior, and super-temporal areas; this reduction in the visual field may be attributed to the helmet visor which not only protruded beyond the forehead, but also was brought down toward the eyes by the weight of the faceshield. Commercial C and D armor also showed a reduction in the visual field in the super-nasal, superior, and super-temporal areas. This reduction in the visual field may be attributed to the helmet visor which not only protruded beyond the forehead, but also was brought down toward the eyes by the weight of the faceshield. The drastic reduction of the inferior area of the visual field in the Commercial C and D armor conditions was due to the high protective collars which rose in front of the face. Measurements of the infero-nasal and infero-temporal areas in these armor conditions were conducted with the collar off; if these areas were measured with the collar on, they too would most likely show drastic reductions in the field of vision.

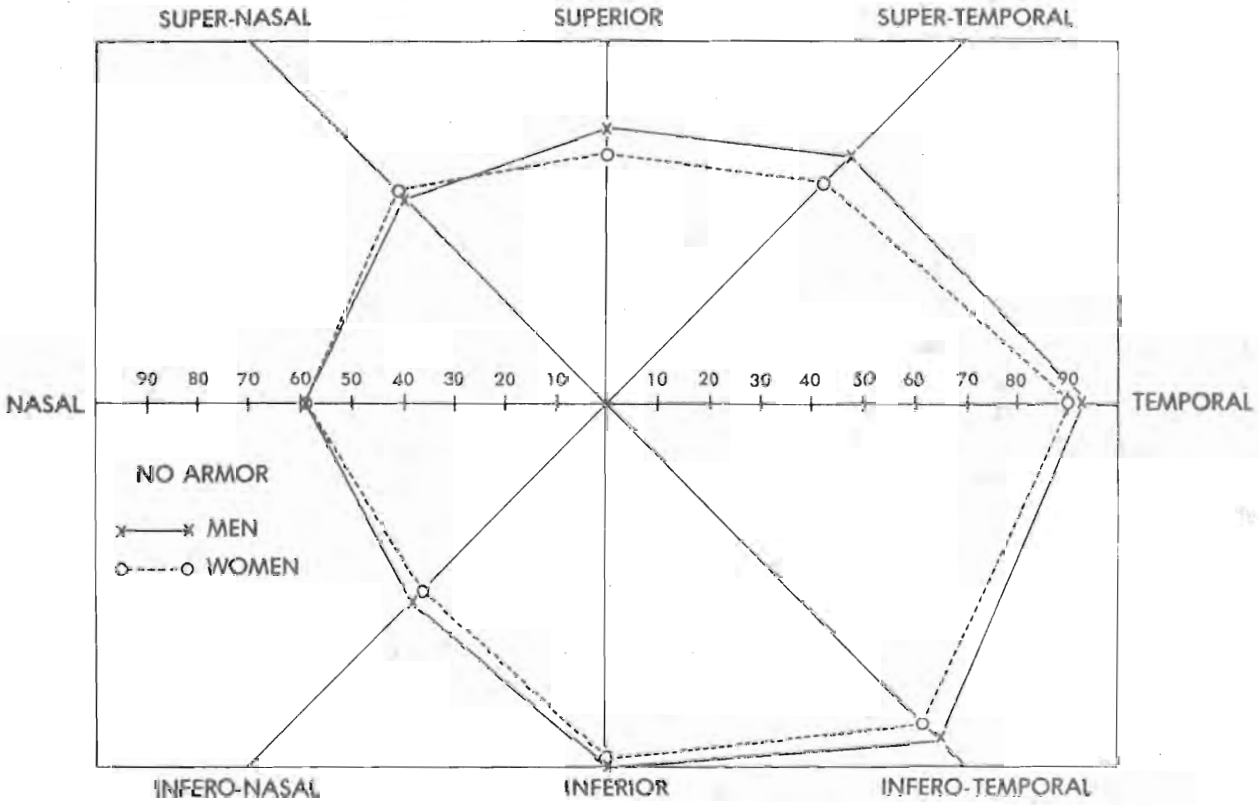

Figure 46. Mean Visual Fields (Both Eyes Combined) of Men and Women in the No Armor Condition.

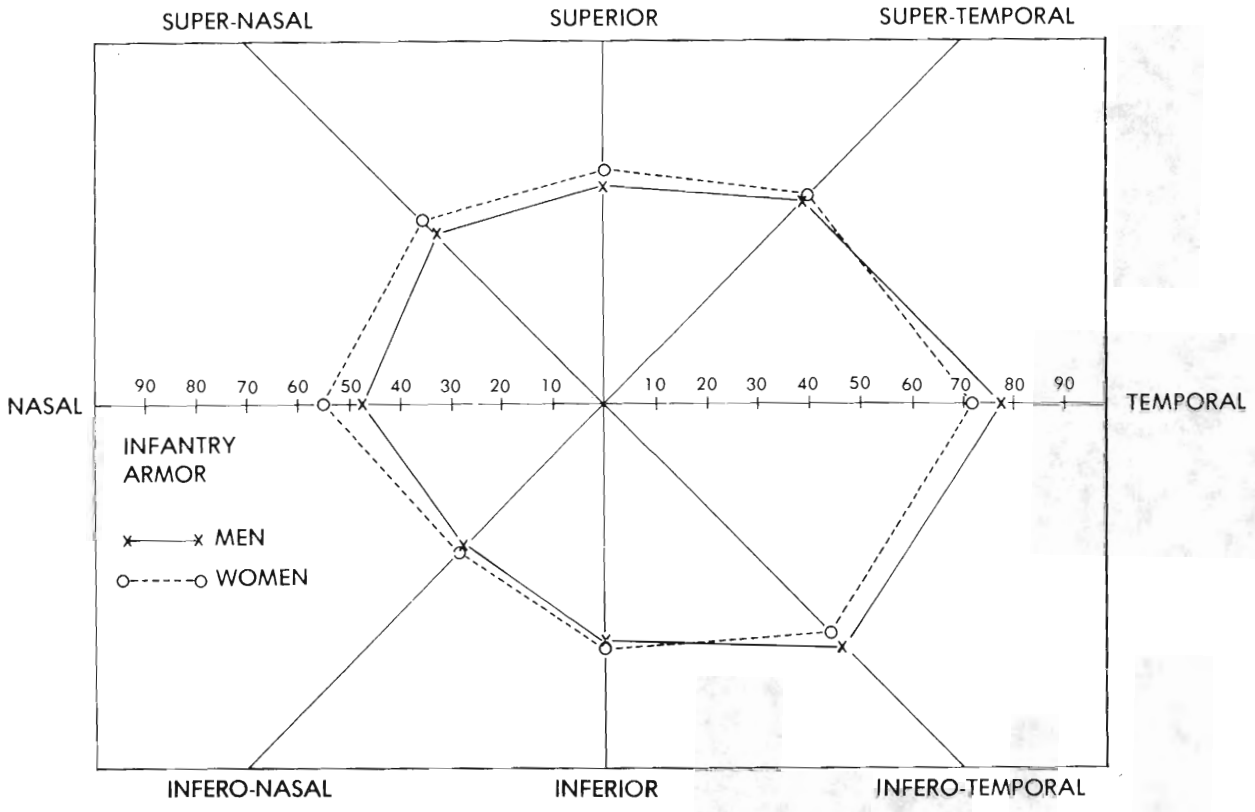

Figure 47. Mean Visual Fields (Both Eyes Combined) of Men and Women in the Infantry Armor Condition.

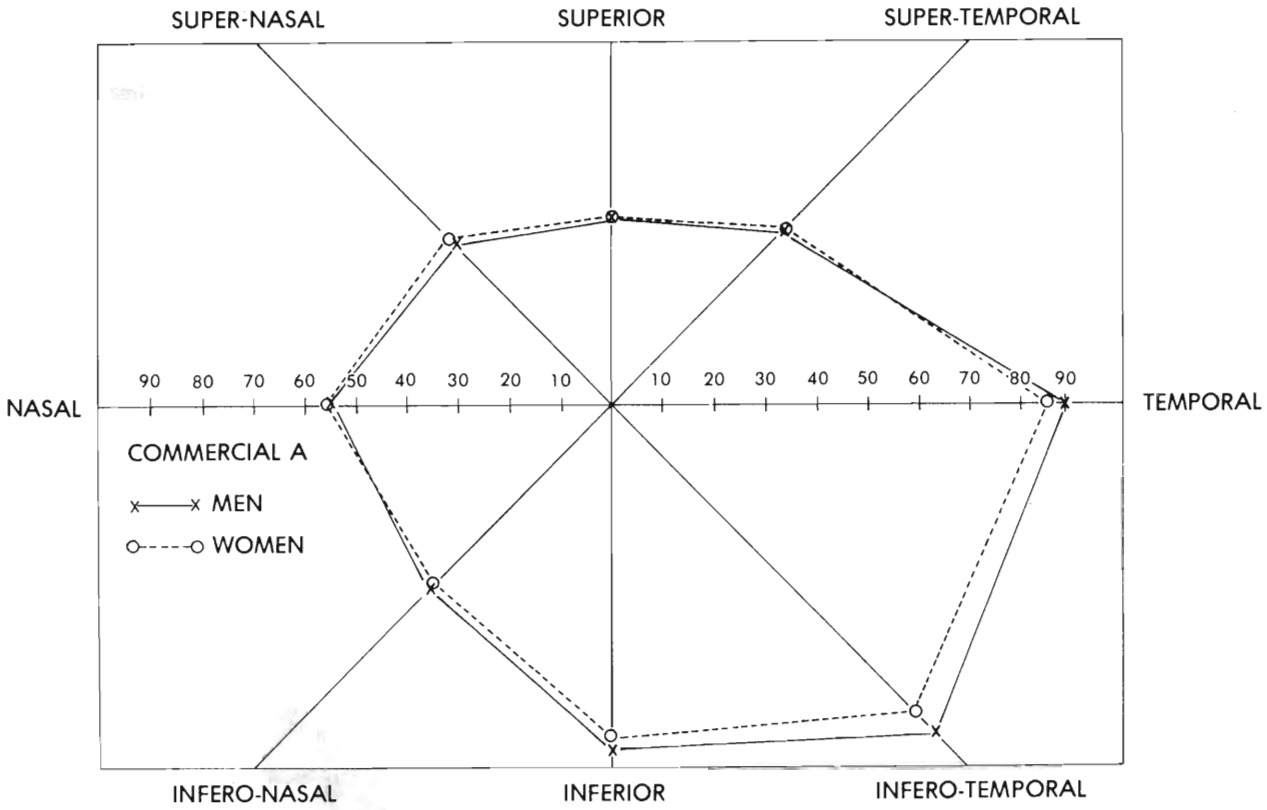

Figure 48. Mean Visual Fields (Both Eyes Combined) of Men and Women in the Commercial A Armor Condition.

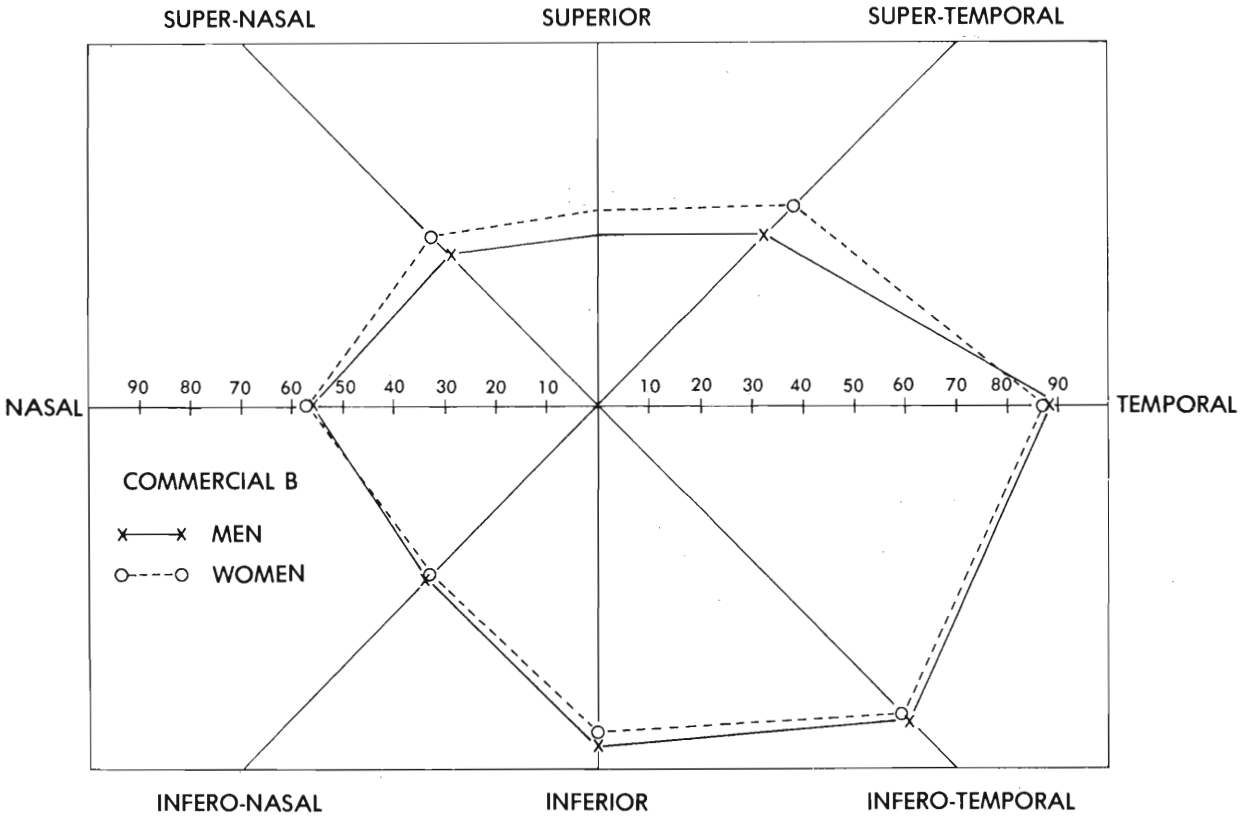

Figure 49. Mean Visual Fields (Both Eyes Combined) of Men and Women in the Commercial B Armor Condition.

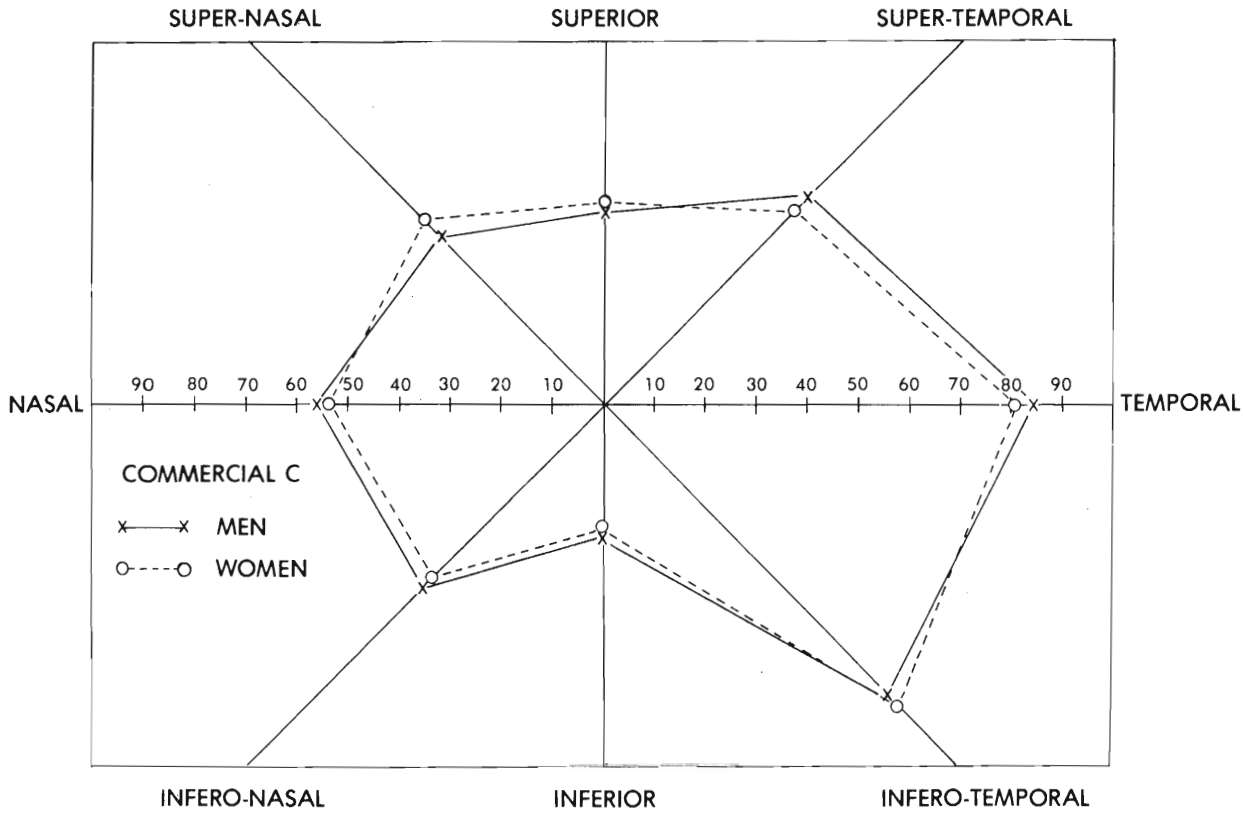

Figure 50. **Mean Visual Fields (Both Eyes Combined) of Men and Women in the Commercial C Armor Condition.**

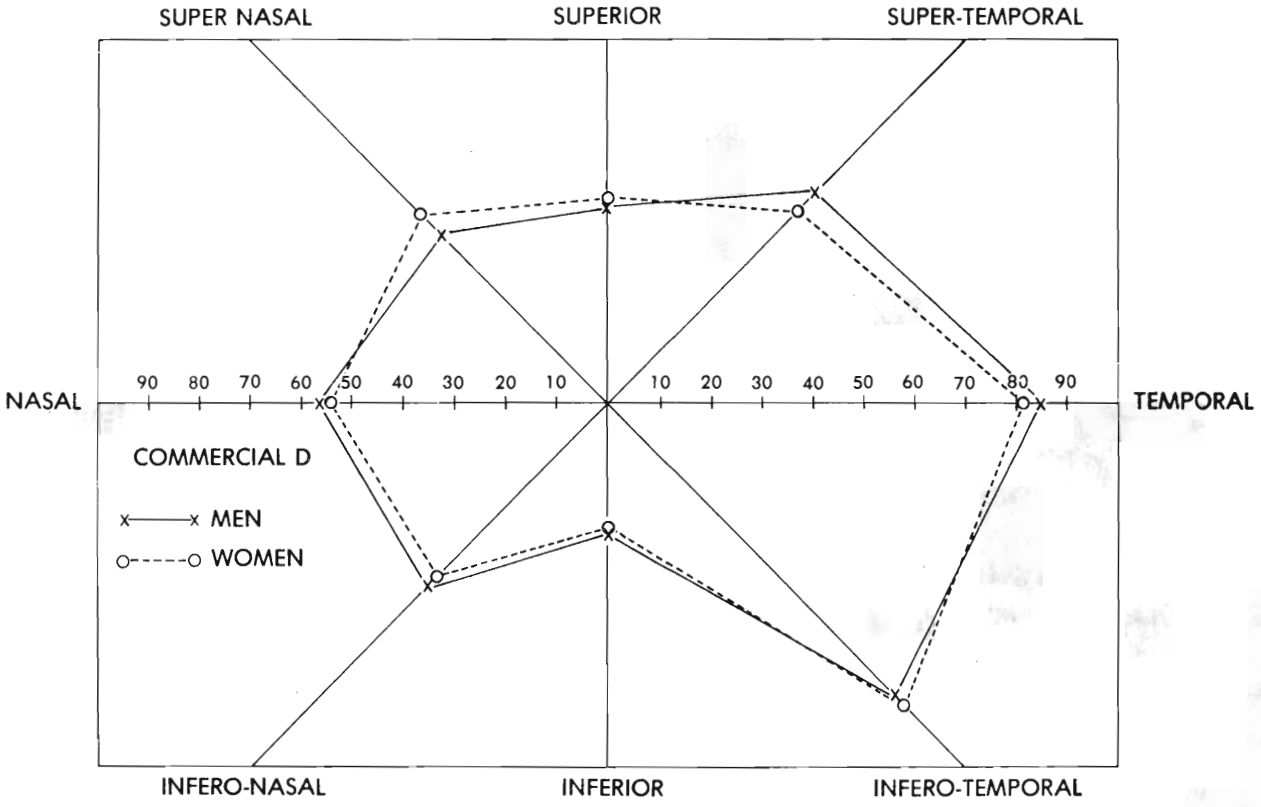

Figure 51. Mean Visual Fields (Both Eyes Combined) of Men and Women in the Commercial D Armor Condition.

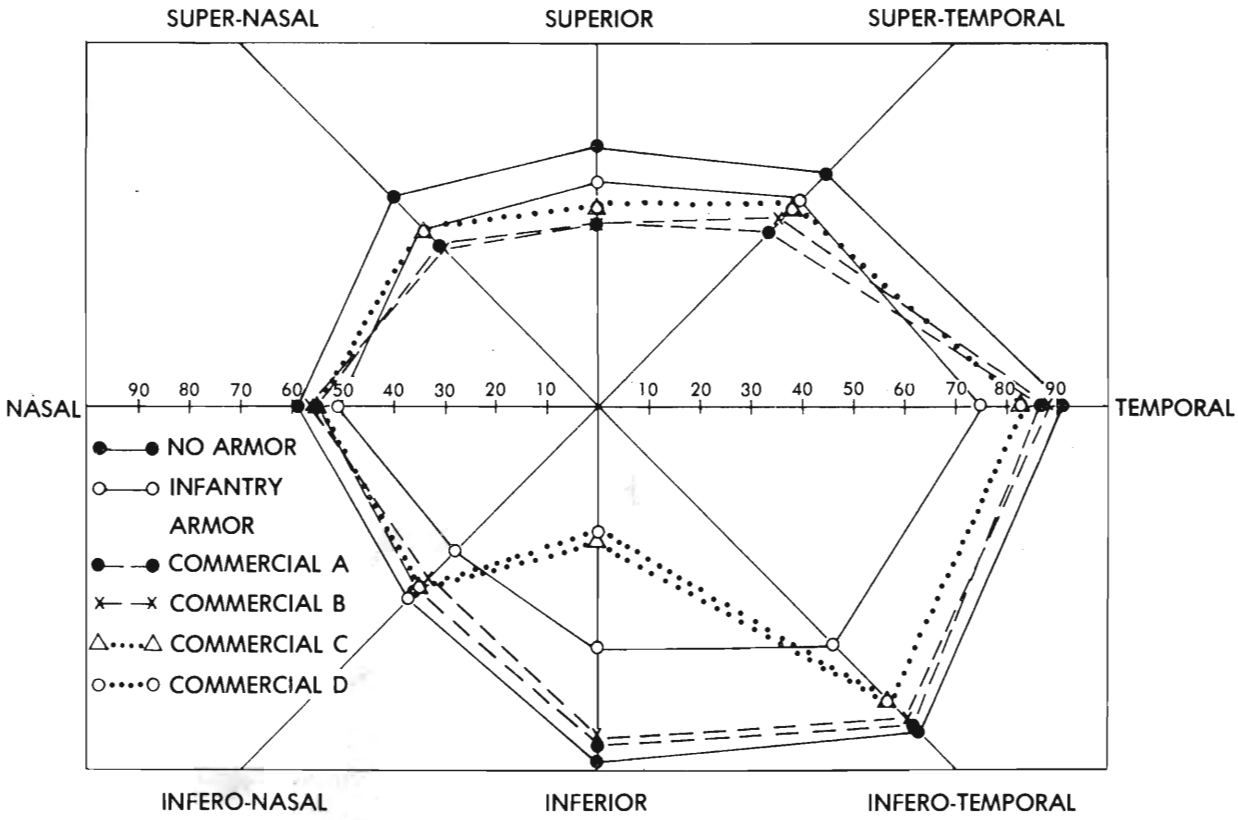

Figure 52. **Mean Visual Fields (Both Eyes Combined, Men and Women Combined) for Each of the Six Armor Conditions.**

Because Commercial A and B armor yielded fields of view similar to the No Armor field of view in all but the three superior areas, it may be stated that Commercial A and B armor conditions marginally conform with that performance characteristic of the Letter Requirement pertaining to vision (para. 5a(4)). Since Commercial C and D armor demonstrated fields of view which were limited both in the superior and inferior areas, it may be stated that Commercial C and D armor conditions do not conform with that performance characteristic of the Letter Requirement pertaining to vision (para. 5a(4)). Designers of future EOD suits of armor should pay particular attention to methods of design which will inhibit the falling of the helmet visor into the field of view (for example, a change in the helmet center of gravity toward the rear), as well as to methods of design which will increase the field of view in the inferior segments (for example, minimizing the height of protective collars).

V. SUBJECTIVE REPORT DATA

Three questionnaires were used in this multifaceted evaluation of EOD armor. The questionnaires are reproduced in Appendix F. The first questionnaire, entitled "Subjective Evaluation I (Gross Mobility)", was administered each time the subject completed all the gross body movements of Investigation I for each of the commercial armor conditions. The second questionnaire, entitled "Subjective Evaluation II (Psychomotor Performance)", was administered each time the subject doffed a suit of commercial armor in Investigation II. Subjective Evaluations I and II were not administered for the two control conditions since these questionnaires were EOD–specific (that is, the subject was asked to judge the performance of faceshields, leggings, etc.). The third questionnaire, entitled "Subjective Evaluation III (Preference)", was administered upon completion of the entire study.

Subjective Evaluation I (Gross Mobility)

On Part A of this questionnaire, the subjects were asked to read a list of 18 design characteristics and to indicate with a number (1, 2, or 3) whether or not they thought the characteristic "needs no improvement" (a rating of "1"), "needs little improvement" (a rating of "2"), or "needs much improvement" (a rating of "3"). Therefore, the higher the score, the more the subject thought that the design characteristic needed to be improved. The medians of these scores across subjects for each design characteristic and commercial armor condition are presented in Table 27; the men's and women's scores were combined since a series of Kolmogorov-Smirnov two-sample tests showed that the men did not differ significantly (α = .05) from the women on their rating of each design characteristic for each commercial armor condition.

A series of Friedman two-way analyses of variance by ranks (χ_r^2) was conducted on the combined ratings of men and women to determine if the ratings of each design characteristic differed as a function of commercial armor condition. The only design charactersitics on which the suits could be differentiated by the subjects were "overall suit weight" ($p<.01$) and "overall suit bulk" ($p<.01$). The Commercial C and D suits of armor were rated as being too heavy. The Commercial D suit of armor was rated as the bulkiest, needing much improvement in that area. In the area of overall bulk, the Commercial C suit of armor was rated as needing little improvement. Both Commercial A and B suits of armor were rated as needing the least improvement of the four suits in the areas of weight and bulk. Subjects rated all helmets as needing improvement in the areas of fit and weight, and rated all collars as needing improvement in the areas of fit and flexibility.

On Part B of this questionnaire, the subjects were asked to rank order five general categories of gross body movement according to how much they were interfered with by the suit of armor they wore during that session. The five categories were: head movements, arm movements, leg movements, torso movements, and walking movements. For each commercial suit of armor, subjects were asked to assign the number "1" to the category of movement most interfered with, the number "2" to the category of movement next most interfered with, and so on until the number "5" was assigned to the category of movement least interfered with.

Table 27

Median Ratings of Garment Design Characteristics for Each Commercial EOD Armor Condition

Design Characteristic	Commercial Armor Condition A	B	C	D	χ^2_r	p
1. helmet fit	1.9	1.8	2.0	2.3	2.53	ns
2. helmet weight	1.4	1.5	1.5	2.6	5.25	ns
3. visibility afforded by helmet	1.0	1.3	1.7	1.4	5.03	ns
4. collar fit	1.2	1.5	2.0	1.4	1.98	ns
5. collar flexibility	1.2	1.5	2.0	2.5	6.18	ns
6. visibility afforded by collar	1.1	1.1	1.7	1.8	5.05	ns
7. shoulder fit	1.3	1.1	1.4	2.5	4.58	ns
8. shoulder flexibility	1.2	1.1	1.8	2.0	6.90	ns
9. chest fit	1.1	1.2	1.1	1.2	0.28	ns
10. chest flexibility	1.1	1.2	1.1	1.2	1.03	ns
11. waist fit	1.1	1.1	1.1	1.1	0.00	ns
12. waist flexibility	1.1	1.1	1.2	1.5	3.05	ns
13. sleeve length	1.5	1.1	1.3	1.7	2.43	ns
14. sleeve flexibility	1.7	1.2	1.8	1.9	4.23	ns
15. pant leg length	1.3	1.3	1.3	1.3	0.18	ns
16. pant leg flexibility	1.3	1.1	1.1	1.3	1.03	ns
17. overall suit weight	1.1	1.3	2.3	2.6	16.83	<.01
18. overall suit bulk	1.3	1.3	1.8	2.5	13.88	<.01

NOTE: Subjects rated each design characteristic according to the following scale: 1 = needs no improvement; 2 = needs little improvement; 3 = needs much improvement.

For each suit of armor, the Kolmogorov-Smirnov two-sample test was applied to each category of movement to determine if there was a significant difference between the men's and women's rankings of interference. No significant differences (α=.05) were found between the sexes. Therefore, a series of Friedman two-way analyses of variance by ranks (χ_r^2) was conducted on the combined men's and women's rankings of each suit of armor to determine if the different categories of movement received significantly different rankings. Each suit of armor was analyzed separately. The median rankings by armor condition are presented in Table 28.

For the Commercial A armor condition, no significant difference was found; that is, the subjects rated all five categories of movement as being equally interfered with during the Commercial A armor condition. For Commercial B armor ($p<.05$), C armor ($p<.01$), and D armor ($p<.01$), the results were significant, and the categories of movements were ranked as follows, from most interfered with to least interfered with: head movements, arm movements, torso movements, leg movements, and walking movements.

Subjective Evaluation II (Psychomotor Performance)

This questionnaire was administered each time the subject doffed a commercial suit of armor in Investigation II. On this questionnaire, the subject was asked to rate the suit of armor on ten bipolar dimensions, or bipolar adjectives, such as heavy-light, hot-cool, stiff-flexible, and uncomfortable-comfortable. The scale on which the subject was to rate the suit of armor ranged from –2 to +2, with "–2" indicating the extreme for the first word in the adjective pair (for example, very heavy), "0" indicating neutral, and "+2" indicating the extreme for the second word in the adjective pair (for example, very light). For each suit of armor, the Kolmogorov-Smirnov two-sample test was applied to each bipolar dimension to determine if there was a significant difference between the men's and the women's ratings. No significant differences (α=.05) were found between the sexes. Therefore, the men's and women's ratings were combined, and a Friedman two-way analysis of variance by ranks (χ^2) was performed on each bipolar dimension in order to determine if the ratings differed as a function of the EOD armor condition. The median ratings for each bipolar dimension are presented in Table 29 along with the results of these statistical analyses. The analyses showed that the Commercial C and D suits were perceived as weighing more, were less well ventilated, were more difficult to breathe in, and the faceshields fogged more readily than the Commercial A and B suits. Thus, the subjects distinguished among the four commercial suits on these four bipolar dimensions, but did not distinguish among the four suits on the remaining six bipolar dimensions.

Two items (#10 and #11) on this questionnaire required the subjects to specify the best characteristic and the worst characteristic of the suit of armor they had just worn. These were open-ended questions. Counts were made of the most frequently cited best characteristic and worst characteristic of each suit of armor. Subjects frequently described the Commercial A suit as permitting much mobility; the uncomfortable helmet with chinstrap was its worst characteristic. The Commercial B suit was also described as permitting much freedom of movement, with its worst characteristic being the uncomfortably tight collar. The Commercial C armor was given no best characteristic (for example, two rated, "getting out of it" and

Table 28

Median Rankings of Categories of Gross Body Movement According to Amount of Interference Imposed by Each Commercial EOD Suit of Armor

Commercial Armor Condition	Category of Movement						
	Head	Arms	Torso	Legs	Walking	χ_r^2	p
A	1.5	2.3	3.2	2.8	4.2	3.98	ns
B	1.2	2.8	3.1	3.7	4.2	12.17	<.05
C	1.2	2.2	3.1	3.5	4.6	18.90	<.01
D	1.3	1.8	3.3	3.8	4.6	33.68	<.01

NOTE: A low number means more interference than a high nnumber.

Table 29

Median Ratings of Bi-Polar Dimensions
for Each Commercial EOD Armor Condition

Bi-Polar Dimension	Commercial Armor Condition A	B	C	D	χ_r^2	p
1. heavy-light	– 0.6	– 0.9	– 1.3	– 1.5	11.43	<.01
2. hot-cool	+0.3	– 0.1	– 0.8	– 0.9	4.43	ns
3. stiff-flexible	– 0.6	– 0.8	– 1.1	– 1.5	7.63	ns
4. poorly ventilated – well ventilated	+0.6	+0.5	– 0.8	– 0.8	11.88	<.01
5. tight-loose	0	– 0.3	+0.3	+0.1	1.50	ns
6. difficult breathing – easy breathing	+.03	+0.8	– 0.7	– 0.5	8.13	<.05
7. faceshield: fogged – clear	+1.5	+0.9	– 0.9	– 1.2	13.03	<.01
8. tired – energetic	– 0.6	– 0.7	– 0.9	– 0.3	1.23	ns
9. uncomfortable – comfortable	– 0.9	– 0.9	– 1.8	– 1.5	2.13	ns
10. dislike – like	– 0.6	– 0.3	– 0.8	– 1.2	3.25	ns

NOTE: Possible scores range from -2 to +2, with "-2" indicating the extreme for the first word in the adjective pair (e.g., very heavy), "0" indicating neutral, and "+2" indicating the extreme for the second word in the adjective pair (e.g., very light).

"taking it off" as its best characteristic); its worst characteristic was its heavy, uncomfortable helmet. The Commercial D armor was described as having an appearance which suggested much protection; its worst characteristic was its heavy helmet.

Subjective Evaluation III (Preference)

This questionnaire was administered immediately upon completion of the entire study. On this questionnaire, the subject was asked to rank each suit for preference for use in a real life bomb disposal situation. The subject, inexperienced in actual EOD work, was asked to imagine being assigned to a bomb disposal unit and to arrange the suits in order of preference. That is, the subject was asked to assign a "1" to the suit most preferred for use in a real life situation, a "2" to the next suit of choice, and so on with a "6" being assigned to the suit least preferred for use in a real life situation. The subjects were asked to rank all six armor conditions since, in real life, wearing no suit at all or wearing only infantry armor may be actual alternatives. For each of the six armor conditions, a Kolmogorov-Smirnov two-sample test was applied to the rankings to determine if there was a significant difference between the men's and the women's rankings; no significant differences (α=.05) were found between the sexes. Therefore, the men's and women's rankings of the armor conditions were combined, and a Friedman two-way analysis of variance by ranks (χ_r^2) was performed on these preference rankings to determine if the rankings differed as a function of armor condition. The analysis showed that the subjects ranked the suits such that the most preferred armor condition for a real life EOD situation was the Commercial C suit of armor (medium rank = 1.4). The next preferred suit was the Commercial D suit (median rank = 2.0), followed by the Commercial B suit (median rank = 3.0), the Commercial A suit (median rank = 3.8) and the Infantry Armor (median rank = 4.8). The No Armor condition (median rank = 6.0) was the least preferred. This rank ordering was statistically significant with χ_r^2 = 41.41, df = 5, $p \leq .001$.

Discussion

The results of Subjective Evaluations I and II were consistent. Commercial suits C and D were consistently reported as having severe disadvantages. Both suits were subjectively reported to be heavy, bulky, poorly ventilated and difficult in which to breathe; in addition, the faceshields fogged in both the C and D armor conditions. Subjective reports about C and D armor in Part B of Subjective Evaluation I showed that both suits (as well as the Commercial A suit) interfered with upper body (head, arms, and torso) movements more than with lower body movements. In subjective Evaluation III, the subjects reported that they would prefer to use Commercial suits C and D before Commercial suits A and B. Given only the information in Subjective Evaluations I and II, this would be surprising. However, the subjects reported that they would choose Commercial suits C and D over Commercial suits A and B for the same reasons that they chose Commercial C and D armor over the Infantry Armor and the No Armor: Commercial suits C and D appeared to the subjects to offer more protection in terms of body coverage. This is supported by the fact that the only time that the subjects listed "protection" as a best characteristic of a suit was when they were rating the Commercial C and D suits. Apparently, the subjects would be willing to put up with the discomfort and restrictions of body movement placed upon them by Commercial suits C and D in order to obtain what appeared to them to be better protection from UXO and IED.

GENERAL DISCUSSION

Major Findings

The object of this report was the evaluation of four commercially available bomb disposal suits with respect to five of the performance characteristics set forth in the Letter Requirement. These performance characteristics are presented below along with the relative performance of each EOD suit of armor.

1. The "total body armor system must – Provide the flexibility necessary for not seriously impeding mobility of the wearer" (para. 5a(3) of the Letter Requirement). This performance characteristic was addressed in both Investigation I (Gross Body Mobility) and Investigation II (Psychomotor Performance and Donning/Doffing), and the results indicate that: (1) Commercial A armor conforms with this performance characteristic both in terms of gross body mobility and fine body mobility; (2) Commercial B armor marginally conforms with this performance characteristic both in terms of gross body mobility and fine body mobility; and (3) both Commercial C armor and Commercial D armor do not conform with this performance characteristic either in terms of gross body mobility or in terms of fine body mobility. In brief, only the Commercial A suit of armor conforms with the performance characteristic.

2. The "total body armor system must – Not impede vision or hearing of the wearer" (para. 5a(4) of the Letter Requirement). This performance characteristic was addressed in both Investigation III (Speech Intelligibility) and Investigation IV (Visual Field), and the results indicate that: (1) all commercial EOD suits of armor conform with this performance characteristic in terms of hearing; (2) Commercial A and Commercial B suits of armor marginally conform with this performance characteristic in terms of vision because Commercial A and B armor partially restricted the superior portions of the visual field; and (3) Commercial C and D armor do not conform with this performance characteristic in terms of vision because both suits of armor severely restricted the superior and the inferior portions of the visual field.

3. The "total body armor system must – Be capable of being worn a minimum of one hour without seriously affecting the accomplishment of the mission" (para. 5a(14) of the Letter Requirement). This performance characteristic was addressed in Investigation II (Psychomotor Performance and Donning/Doffing), and the results indicate that all commercial EOD suits conform with this performance characteristic; specifically, regardless of the type armor worn, psychomotor performance did not deteriorate during the course of each one-hour test session conducted in a room maintained at 18.3°C (65°F).

4. The "total body armor system must – Be capable of donning or doffing within five minutes" (para. 5a(15) of the Letter Requirement). This performance characteristic was addressed in Investigation II (Psychomotor performance and Donning/Doffing), and the results indicate that all commercial EOD suits conform with it.

5. The "total body armor system must – Not inhibit head movement, restrict breathing or prevent talking" (para. 5a(16) of the Letter Requirement). This performance characteristic was addressed in Investigation I (Gross Body Mobility), Investigation III (Speech Intelligibility), and Investigation V (Subjective Report), and the results indicate that: (1) Commercial A armor conforms with this performance characteristic in terms of head movement and ease of breathing and marginally conforms with this performance characteristic in terms of ability to be heard while talking; (2) Commercial B armor conforms with this performance characteristic in terms of ease of breathing, marginally conforms with this performance characteristic in terms of ability to be heard while talking, and does not conform with this performance characteristic in terms of head movement; and (3) both Commercial C and Commercial D armor do not conform with this performance characteristic either in terms of head movement, ease of breathing, or the ability to be heard while talking.

Minor Findings

Although not the main object of this report, data were gathered during the course of this study which shed light on the performance of the four commercial EOD suits with respect to four additional performance characteristics set forth in the Letter Requirement. These performance characteristics are presented below along with the performance of each EOD suit of armor.

1. The "total body armor system must – Weigh no more than 50 lbs. (size medium), exclusive of ancillary equipment" (para. 5a(1) of the Letter Requirement). During the course of this study, the commercial EOD armor systems and their components were weighed, and the results (see Table 2) indicate that both Commercial A armor and Commercial B armor conform with this performance characteristic. Size medium Commercial A armor and size medium Commercial B armor weigh 17.28 kg. (38.02 lbs.) and 19.94 kg. (43.87 lbs.), respectively. Since size medium was unavailable in either Commercial C or Commercial D armor, it is impossible to say that these two suits of armor conform with this performance characteristic. Of the two suits of armor (Commercial C and Commercial D), it is more likely that Commercial C armor would conform with this performance characteristic given the availability of a size medium suit since the size large Commercial C suit is only 1.09 kg. (2.40 lbs.) over the 22.73 kg. (50 lbs.) limit, while the size large Commercial D suit is 4.63 kg. (10.19 lbs.) over the 22.73 kg. (50 lb.) limit.

2. The "total body armor system must – Be produced in the minimum number of sizes to accommodate the 5th through the 95th percentile for full protection of – EOD personnel (male and female)" (para. 5a(1) of the Letter Requirement). Since EOD personnel may be male or female and are not selected for body size, the EOD suit of armor must accommodate the smallest female through the largest male. The sample of subjects used in this study included both males and females. The largest male (subject 6, see Table 1) in this study approximated the 95th percentile male as described in the 1966 anthropometric survey of Army men.[19] This male found the fit of Commercial A and B armor to be lacking:

[19] R. M. White and E. Churchill. The body size of soldiers: US Army Anthropometry – 1966. Technical Report 72–51–CE, Natick, MA: US Army Natick Laboratories, 1971.

with both suits of armor (size large) the sleeves were approximately 10 centimeters too short and the leggings were approximately 12 centimeters too short. This male experienced no difficulty in being fit into the Commercial C and D suits of armor.

None of the women who participated in this study (see Table 1) was small enough to be categorized as a 5th percentile female according to height, weight, bust circumference, or waist circumference as described in the 1977 survey of Army women.[20] The shortest women (S#7) approximated the 20th percentile in height. Nevertheless, all women found Commercial C and D suits of armor to be too large for them (not unexpected, since these suits were only provided in size large) and the three shortest women (Ss# 7, 8, and 11) found Commercial A and B suits of armor to be too large for them. Specifically, all women found with respect to Commercial suits C and D that the sleeves were too long, the leggings were too long, and the suits in general had too much bulk (i.e., their torso circumferences, arm circumferences, and leg circumferences were too small to fill out the suits). The Commercial D suit of armor was particularly poor in terms of fit because its long apron almost touched the floor, and the sleeves had to be rolled up approximately 15 centimeters to permit the subjects to perform the manual dexterity tasks of Investigation II. Figure 23 shows the poor fit of the Commercial D suit of armor on a female test subject; in that figure, the left sleeve has been turned up to demonstrate the excess sleeve length. The three shortest women found the small size Commercial A and B suits of armor to provide poor fits in terms of the sleeves being too long and bulky and in terms of the waist strap not providing enough adjustment to permit the leggings to be securely fastened at the waist. In conclusion, it may be said that (1) Commercial A and B armor provided poor fits for the 95 percentile man and 20th percentile women and thus do not conform with this performance characteristic (para. 5a(11) of the Letter Requirement); and (2) although Commercial C and D armor provided acceptable fits for the 95th percentile man, there were no size small suits to try on the women and thus there were insufficient data to judge whether or not Commercial C and D suits of armor conform with this performance characteristic.

3. The "total body armor system must – Be capable of doffing extremeties [sic] and lower abdomen (below the waist) protection without removal of head, chest and upper abdomen protection" (para. 5a(20) of the Letter Requirement). Of the four commercial EOD suits of armor examined during the course of this study, only Commercial B armor came close to conforming with this performance characteristic; doffing of the Commercial B sleeves and leggings could be readily accomplished, but their doffing necessitated removal of the armor collar and bib which compromised protection in the chest and head/neck areas. Commercial A, C, and D suits of armor do not conform with this performance characteristic: doffing of Commercial A's sleeves required removal of the armor vest; Commercial C armor did not

[20] E. Churchill, T. Churchill, J. T. McConville, and R. M. White. Anthropometry of Women of the US Army – 1977: Report No. 2 The basic univariate statistics. Technical Report NATICK/TR–77/024. Natick, MA: US Army Natick Research and Development Command, 1977.

permit independent doffing of any extremity armor; and Commercial D armor permitted only doffing of the leg armor. In sum, Commercial B armor marginally conforms with this performance characteristic, while Commercial A, C, and D armor systems do not conform with this performance characteristic.

4. The "total body armor system must – Be compatible with the environmental clothing, eyeglasses, breathing apparatus, communication equipment and other ancillary equipment authorized for use in performing an EOD mission" (para. 5a(22) of the Letter Requirement). During the course of this study, two types of ancillary equipment were addressed in terms of compatibility with each of the four EOD suits of armor. It was found that eyeglasses could be readily worn with all four commercial suits of armor, but that it was extremely uncomfortable to wear eyeglasses in the Commercial C and D armor (the tight earphones would press the stems of the eyeglass frames against the head in the area of the temple and ears). Stethoscopes are often used by EOD personnel in rendering safe an IED; an electrically aided (earplug type) stethoscope as well as a standard clinical stethoscope are compatible with the Commercial A and B armor, but are incompatible with Commercial C and D armor (the helmets' earphones preclude the use of a stethoscope). With respect to eyeglasses and stethoscopes, it may be stated that Commercial A and B armor conform with this performance characteristic, while Commercial C and D armor systems do not.

Table 30 summarizes the performances of the four commercial EOD suits in relation to the nine performance characteristics of the Letter Requirement discussed above. This table shows that of the 13 categories for rating: (1) Commercial A armor conforms with nine of the categories, marginally conforms with two of the categories, and does not conform with two of the categories; (2) Commercial B armor conforms with six of the categories, marginally conforms with five of the categories, and does not conform with two of the categories, (3) and (4) Commercial C and D armor each conform with three of the categories, marginally conform with none of the categories, and do not conform with eight of the categories (two categories could not be rated due to insufficient data).

Table 30

Conformance of Four Commercial EOD Suits of Armor With the Performance Characteristics of the Letter Requirement (LR)

Performance Characteristic	Commercial EOD Armor A	B	C	D
1. Weigh no more than 50 lbs. size medium; LR para. 5a(1)	+	+	Insufficient Data	Insufficient Data
2. Mobility; LR para. 5a(3)				
gross	+	(+)	o	o
fine	+	(+)	o	o
3. Vision & Hearing: LR para. 5a(4)				
vision	(+)	(+)	o	o
hearing	+	+	+	+
4. Size Range; LR para. 5a(11)	o	o	Insufficient Data	Insufficient Date
5. One-hour wear; LR para. 5a(14)	+	+	+	+
6. Donning/doffing; LR para. 5(15)	+	+	+	+
7. LR para. 5a(16)				
head mobility	+	o	o	o
breathing	+	+	o	o
talking	(+)	(+)	o	o
8. Doff extremities; LR para. 5a(20)	o	(+)	o	o
9. Compatibility w/ancillary equipment, LR para. 5a(22)	+	+	o	o

NOTE: + = conforms with performance characteristic
(+) = marginally conforms with performance characteristic
o = does not conform with performance characteristic

Influence of Sex of the Wearer on Performance in EOD Armor

Half the test subjects utilized in this study were male and half were female. The data analyses showed that there were no significant differences in performance between men and women on hearing, vision, speech communication, or subjective report. As was pointed out in the individual discussion sections of this report, the difference between men's performance and women's performance (when it occurred) was basically due to the smaller body dimensions of women in general, and not necessarily due to the differences between men and women in terms of differences in relative body proportions. That is, when women performed more poorly than men, it appeared to be due to the overall smaller dimensions of women. This hypothesis is supported by the fact that, when differences occurred between men and women, they often occurred only with EOD suits (such as Commercial C and D suits) which came only in a size large.

Doffing time was the only dependent variable on which a significant main effect for sex was found in the entire study. Women consistently took longer to doff their suits of armor, regardless of the type of armor being doffed. The reason for this sex difference was unclear, but it appeared to be related to motivational and expectational differences between men and women concerning their roles as test subjects.

Given the large number of dependent variables measured during the course of this study, it was surprising that there were not more sex differences. The loose fit of the EOD protective armor may have precluded any serious differences in performance between men and women which ordinarily would have been caused by the differences in body proportions of men and women. Nevertheless, since the EOD occupational specialty is open to both men and women, it is important that researchers and developers continue to monitor the performance of both men and women during the evaluation of future prototype EOD ensembles.

Minor Deficiencies of Garments

In this section minor deficiencies of the separate EOD suits will be presented. The deficiencies are termed "minor" because they did not interfere with movement, vision, hearing, or speech but were annoying in that they required attention by the experimenter (in terms of small repairs). Such deficiencies would not be acceptable to the consumer.

Commercial A armor. This suit of armor had three minor deficiencies: (1) In addition to the "full-down" position, the helmet's faceshield was designed with three "up" positions; the faceshield had a strong tendency to fall down into the wearer's face without notice. (2) The two sleeves were connected by an elastic strap across the back; the strap had a tendency to move down the wearer's back so that the sleeves and strap required constant adjustment. (3) The hook-and-pile fastener on the leggings' waist belt had a tendency to unfasten during trunk flexion, kneeling, and upper leg flexion movements; this deficiency required frequent refastening by the experimenter.

Commercial B armor. This suit of armor had two minor deficiencies: (1) As with the Commercial A armor, the helmet's faceshield had a strong tendency to fall from the "up"

position without warning. (2) As with the Commercial A armor, the hook-and-pile fastener on the leggings' waist belt had a tendency to unfasten during trunk flexion, kneeling, and upper leg flexion movements.

Commercial C armor. This suit of armor had five minor deficiencies, four of them in the helmet: (1) During trunk flexion movements, the two snaps holding the breast plate in its pocket would sometimes unsnap, necessitating re-snapping. (2) The helmet's translucent hollow communication tube fell off the helmet and could not be repaired in the laboratory workshop. (3) The square-shaped plastic base which connected the translucent tube to the helmet fell off the helmet and had to be glued back onto the helmet. (4) The helmet's chinstrap fell off during one experimental session; this was due to a bolt-nut separation at the helmet surface and was quickly repaired. (5) The pile material inside the forward section of the helmet separated from the helmet and had to be reglued to the helmet.

Commercial D armor. This suit of armor had five minor deficiencies. Four of the deficiencies involved the helmet, and were the same helmet deficiencies encountered with Commercial C armor; Commercial C and D armor utilize the same helmet. The fifth deficiency involved the hook-and-pile fastener running the length of the jacket apron from under the left arm to the hem of the garment; this hook-and-pile fastener came partially undone during trunk flexion, kneeling, and upper leg flexion movements and had to be refastened by the experimenter at frequent intervals.

The "Potential For Use" Factor

This entire report has addressed performance characteristics of the Letter Requirement which do not directly relate to the main reason for EOD armor, which is **protection.** An EOD suit of armor may be in full conformance with all nine performance characteristics addressed in this report, but provide very little in the way of protection, and therefore, would be of little or no use to EOD personnel. Conversely, an EOD suit of armor may be in full conformance with the Letter Requirement in terms of protection from IED and UXO, but if it does not conform to other performance characteristics in the Letter Requirement, it would be of little or no use to EOD personnel.

During the course of this study, it has been shown that EOD suits which **appear** to offer much protection (that is, Commercial C and D suits) will be chosen for real-life use over suits which **appear** to offer less protection (that is, Commercial A and B suits). This is the case even though the less preferred suits may offer more mobility, less weight, less bulk, less restricted vision, better breathing, better speech communication, and more compatibility with ancillary equipment. Since armor protection characteristics of the four commercial EOD suits were unknown to the test subjects, it was the appearance of protection (rather than actual protection) which heavily influenced a suit's "potential for use".

After data collection for this formal study was completed, the four commercial EOD suits were loaned to a US Army EOD field unit for their use and comments. Their subjective comments mirrored those of the test subjects. They found commercial suits C and D to be heavier, more restrictive, and to appear to offer more protection than Commercial suits A and B. As a result, when two real-life missions were executed, it was the Commercial C and

D suits which were brought to the mission site for actual use. When asked their reasons for actually using Commercial C and D suits, the EOD personnel cited the "better protection" offered by these suits. As with the laboratory test subjects, EOD personnel in the field were apparently willing to put up with the discomfort and restrictions of body movement placed upon them by the Commercial C and D suits in order to obtain what appeared to be better protection from UXO and IED.

Researchers and developers of EOD armor must be aware of this "potential for use" factor when striving to meet the requirements of the Letter Requirement. That is, researchers and developers must be aware that EOD personnel in the field may flatly refuse to use a garment because it appears to offer little protection, and also may flatly refuse to use a high protection-appearing garment because it weighs too much (or hinders vision too much, or hinders leg movement too much, etc.). Each EOD garment considered for adoption should be evaluated in the laboratory and in the field not only to determine if it meets the performance characteristics of the Letter Requirement but also to determine if it has a high "potential for use" by EOD personnel.

CONCLUSIONS

1. Objective measures of gross body mobility and psychomotor performance indicated that only the Commercial A suit of armor conforms with the requirement that the total body armor system provide the flexibility necessary for not seriously impeding the mobility of the wearer. The largest decrements in mobility as a function of wearing EOD armor occurred when the Commercial C and D suits of armor were worn.

2. Objective measurement of the ability to correctly hear human speech indicated that all four commercial suits of armor conform with the requirement that the total body armor system not impede the hearing of the wearer.

3. Objective measurement of the ability of the wearer of EOD armor to be heard while speaking indicated that all four suits of EOD armor impaired the ability of the wearer to be heard. Commercial suits C and D impaired speech to such a degree that they do not conform with the speech communication requirement.

4. Objective measurement of the limits of the visual field of subjects outfitted in EOD armor indicated that Commercial A and B armor reduced the visual field in three superior areas while Commercial C and D armor reduced the visual field in six areas (three superior and three inferior areas). Commercial C and D armor were judged to be not in conformance with the requirement that the total body armor system not impede the vision of the wearer.

5. Objective measurement of psychomotor performance over a period of one hour indicated that all four commercial suits conform with the requirement that the total body armor system be capable of being worn a minimum of one hour without seriously affecting performance.

6. Objective measurement of donning speed and doffing speed indicated that all four commercial suits conform with the requirement that the total body armor system be capable of being donned or doffed within five minutes.

7. Subjective measurement of ease of breathing indicated that Commercial C and D suits of armor do not conform with the requirement that the total body armor system not restrict breathing.

8. Measurements of the weight of each Commercial EOD suit of armor indicated that Commercial A and B suits of armor conform with the requirement that the total body armor system (size medium) weigh no more than 50 lbs.; insufficient data were available on Commercial C and D suits of armor to judge whether or not they met the weight requirement.

9. Commercial A and B suits of armor provided poor fit for the 95th percentile man and the 20th percentile woman and, thus, do not conform with the requirement that the total body armor system must accommodate the 5th through the 95th percentile of EOD personnel; insufficient data were available on Commercial C and D suits of armor to judge whether or not they met this requirement.

10. None of the four commercial EOD suits conforms with the requirement that the extremities and lower abdomen protection be capable of being doffed without removal of head, chest, and upper abdomen protection.

11. Eyeglasses and stethoscopes were found to be compatible with Commercial A and B armor, while Commercial C and D armor could not easily accommodate these items. Therefore, as measured by these indexes, Commercial A and B suits of armor conform with the requirement, and Commercial C and D suits of armor do not conform with the requirement that the total body armor system must be compatible with authorized ancillary equipment.

12. Differences between men's and women's performance while wearing EOD armor was infrequent. When differences did occur, they were basically due to the smaller body dimensions of women in general and not necessarily due to the differences between men and women in terms of differences in relative body proportions.

REFERENCES

Churchill, E., T. Churchill, J. T. McConville, and R. M. White. Anthropometry of Women of the US Army – 1977: Report No. 2 – The basic univariate statistics. Technical Report NATICK/TR–77/024. Natick, MA: US Army Natick Research and Development Command, 1977.

Dusek, E. R. Standardization of tests of gross motor performance. Technical Report EP–81. Natick, MA: US Army Quartermaster Research and Engineering Center, 1958.

Duske, E. R. and W. H. Teichner. The reliability and intercorrelations of eight tests of body flexion. Technical Report EP–31. Natick, MA: US Army Quartermaster Research and Development Center, 1956.

Hines, M. and J. O'Connor. A measure of finger dexterity. **Journal of Personnel Research, 4**, 379–382, 1926.

House, A. S., C. E. Williams, M. H. L. Hecker, and K. D. Kryter. Articulation testing methods: consonantal differentiation with a closed response set. **Journal of the Acoustical Society of America, 37**, 158–166, 1965.

Letter Requirement (LR) for body armor for explosive ordnance disposal (EOD) units (ACN 21203). Fort Monroe, Virginia: Headquarters, United States Army Training and Doctrine Command, 6 February 1978.

Lockhart, J. M. and C. K. Bensel. The effects of layers of cold weather clothing and type of liner on the psychomotor performance of men. NATICK/TR–77/018. Natick, MA: US Army Natick Research and Development Command, 1977.

McGinnis, J. M., J. M. Lockhart, and C. K. Bensel. A human factors evaluation of cold-wet handwear. Technical Report 73–23–PR. Natick, MA: US Army Natick Laboratories, 1972.

Military Standard, MIL–STD–1472B. Human Engineering Design Criteria for Military Systems, Equipment and Facilities. Washington, DC: Department of Defense, 1974.

Saul, E. V. and J. Jaffe. Effects of clothing on gross motor performance. Technical Report EP–12. Natick, MA: US Quartermaster Research and Development Center, 1965.

White, R. M. and E. Churchill. The body size of soldiers: US Army Anthropometry – 1966. Technical Report 72–51–CE. Natick, MA: US Army Natick Laboratories, 1971.

APPENDIX A

LETTER REQUIREMENT FOR EOD ARMOR

DEPARTMENT OF THE ARMY
HEADQUARTERS UNITED STATES ARMY TRAINING AND DOCTRINE COMMAND
FORT MONROE, VIRGINIA 23651

ATCD-F-S 6 February 1978

SUBJECT: Letter Requirement (LR) for Body Armor for Explosive Ordnance Disposal (EOD) Units, USA TRADOC ACN 21203

SEE DISTRIBUTION

1. Reference: AR 71-9.

2. Attached at Inclosure 1 is the approved TRADOC/DARCOM Letter Requirement for Body Armor for Explosive Ordnance Disposal Units. The following information is applicable to this document:

a. SYSTEM DESIGNATION: Non-major.

b. MATERIEL DEVELOPER: DARCOM.

c. COMBAT DEVELOPER: TRADOC.

d. USER REPRESENTATIVE: TRADOC.

e. TRAINER: TRADOC.

f. LOGISTICIAN: USALEA.

g. CARDS REFERENCE NUMBER: 1414R.

h. OPERATIONAL TEST RESPONSIBILITY: TRADOC.

i. TRADOC PROPONENT ACTIVITY: USAMMCS.

3. Subject LR is forwarded to major Army commands, other services, and DOD agencies for harmonization and to all other addressees for information.

FOR THE COMMANDER:

J. M. LARKINS
LTC, AGC
Assistant AG

1 Incl
as

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ATCD-F-S 6 February 1978
SUBJECT: Letter Requirement (LR) for Body Armor for Explosive Ordnance Disposal (EOD) Units, USA TRADOC ACN 21203

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SUBJECT: Letter Requirement (LR) for Body Armor for Explosive Ordnance Disposal (EOD) Units, USA TRADOC ACN 21203

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LETTER REQUIREMENT (LR) FOR
BODY ARMOR FOR EXPLOSIVE ORDNANCE DISPOSAL
(EOD) UNITS (ACN 21203)

1. Title of the Item. Armor, Body, EOD Protective.

2. Statement of the Need.

a. An urgent need exists for body armor for EOD personnel engaged in operations involving small unexploded explosive ordnance (UXO) and improvised explosive devices (IED). The armor will be used while providing EOD assistance to US military forces, US Government departments and agencies, and civil authorities. It will provide protection to the wearer from high speed fragments commonly associated with UXO and IED.

b. The target time frame for deployment is 1st Quarter FY 82.

c. CARDS Reference Number:

3. Justification.

a. Explosive Ordnance Disposal (EOD) personnel currently have no adequate protection against fragments from exploding munitions/improvised explosive devices. Current EOD publications for ammunition depot cleanups, IED and improved conventional munitions require EOD personnel to wear protective clothing. Additionally, there is a need for protection when approaching known and unknown munitions during render safe/neutralizing procedures; and, while moving and transporting hazardous items to a safe disposal area. Current body armor is not specifically designed for an EOD operation in providing protection to the wearer from high speed fragments associated with exploding ordnance items and IED.

b. Approach to and render safe/neutralization of small known/unknown ordnance and improvised devices has always been hazardous due to the unlimited types of possible fuzing; i.e., acoustic, anti-disturbance, time delay, remote controlled, etc. Body armor providing personnel protection would not only greatly enhance individual safety, but would also decrease incident response time and increase unit operational efficiency.

c. Transportation accidents and ammunition depot disasters usually involve numerous sensitive munitions in a hazardous condition which technically require EOD personnel to destroy them in place. The mere quantity and close proximity between items precludes detonation in place; thus, although extremely hazardous, manual

handling procedures are presently the only effective methods available. Tactical or political considerations may require not only speed, but also the presence of several EOD teams in the hazard area at the same time. Without adequate protection, errors in render safe procedures coupled with the expiration of an armed random delay fuze might kill, maim or injure numerous personnel. The use of the body armor would significantly mitigate the probability of mass casualities, thus providing the opportunity for a more effective utilization of personnel in high priority areas.

4. Basis of Issue. Geographical areas of use include Korea, Hawaii, Alaska, Panama Canal Zone, Europe and CONUS. CTA basis of issue will be one per individual, MOS 55D and SSI 75D, assigned to a TOE Explosive Ordnance Disposal Detachment or a TDA position actively engaged in field EOD operations.

5. Principal Characteristics.

a. Performance Characteristics - total body armor system must:

(1) Weigh no more than 50 lbs (size medium), exclusive of ancillary equipment (i.e., communication and breathing apparatuses).

(2) Not be a missile hazard by becoming a secondary source of fragmentation.

(3) Provide the flexibility necessary for not seriously impeding mobility of the wearer with respect to accomplishment of the mission.

(4) Not impede vision or hearing of the wearer with respect to accomplishment of the mission.

(5) Be capable of being worn and stored in climatic Category 1 thru 7 as defined in AR 70-38.

(6) Be sufficiently rugged to withstand ground vehicle transportation over tertiary roads, trails, beaches and cross-country with minimal adverse effects.

(7) When properly preserved and packaged, have a storage life of at least ten years in covered depot storage without degradation of its fragmentation stopping capability.

(8) Possess maximum resistance to rust, fungus and rot.

(9) Provide moisture, mildew and tear resistance to the outer surface.

(10) Have a neutral and inconspicuous color to the outer material.

(11) Be produced in the minimum number of sizes to accommodate the 5th thru the 95th percentile for full protection of, and efficient utilization by EOD personnel (male and female).

(12) Not create a static electricity charge, when worn in combination with standard issue clothing and equipment, sufficient to detonate standard military electric blasting caps.

(13) Not create a spark or magnetic hazards through the use of metallic buttons or snap and slide fasteners.

(14) Be capable of being worn a minimum of one hour without seriously affecting the accomplishment of the mission.

(15) Be capable of donning or doffing within five minutes.

(16) Not inhibit head movement, restrict breathing or prevent talking to a degree that would seriously affect the accomplishment of the mission.

(17) Insure that protection provided to the vital areas of the back, chest and upper abdomen will have a .98 probability of withstanding complete penetration by the below listed weight and velocity fragments:

FRAGMENT WEIGHT	VELOCITY IN FT PER SECOND (fps)
2 grains	5150 fps
4 grains	4725 fps
16 grains	3600 fps
64 grains	2750 fps

(18) Insure that protection provided to the back and sides of the head will have a .98 probability of withstanding complete penetration by the below listed weight and velocity fragments:

FRAGMENT WEIGHT	VELOCITY IN FT PER SECOND (fps)
2 grains	4000 fps
4 grains	3000 fps
16 grains	2500 fps
64 grains	1900 fps

(19) Insure that protection provided to the face, neck, arms, legs, back and lower abdomen will have a .98 probability of withstanding complete penetration by the below listed weight and velocity fragments:

FRAGMENT WEIGHT	VELOCITY IN FT PER SECOND (fps)
2 grains	2550 fps
4 grains	2225 fps
16 grains	1700 fps
64 grains	1300 fps

"The fragment simulator shall be a Right Circular Cylinder (RCC) with a length to diameter $(\frac{L}{D})$ ratio of 1."

(20) Be capable of doffing extremeties and lower abdomen (below the waist) protection without removal of head, chest and upper abdomen protection.

(21) Nuclear survivability is not required because the system is not critical to mission accomplishment in a nuclear conflict.

(22) Be compatible with the environmental clothing, eye-glasses, breathing apparatus, communication equipment and other ancillary equipment authorized for use in performing an EOD mission.

(23) Be resistant to degredation of the ballistic characteristics due to sweat, water or the climatic conditions expressed in Category 1 thru 7.

b. There are no communication security (COMSEC) or electronic counter-countermeasure (ECCM) requirements applicable to this system. The system will cause no adverse effects on the environment.

c. Reliability, Availability and Maintainability (RAM).

(1) Reliability.

(a) The body armor is a passive device that cannot be associated with a particular mission profile (MP) or operational mode summary (OMS); therefore, the statement of a minimum acceptable value (MAV) of reliability is meaningless and need not be expressed, expecially in view of the previously cited protection characteristics.

(b) The body armor will have no durability failures. A failure in the system due to failure to prevent fragment penetration of those fragments listed in paragraphs (17), (18) and (19) above will be construed a catastrophic failure rather than that of the durability type.

(2) Availability - Operational availability is considered to be 100 percent in that no preventive or unscheduled maintenance of the type considered to cause the body armor system to be non-available is anticipated.

6. Testing Required.

a. Operational Test II - To determine the user's assessment of the body armor's operational suitability and effectiveness for acceptability into the Army.

b. Operational test objectives to be addressed are identified in paragraph 5a(3), (4), (5 except storage), (6), (7), (14), (15), (16), (20), (22) and (23).

c. Developmental Tests - To be provided by the materiel developer (DARCOM)

d. Schedules and Milestones.

(1)	Engineering Design (ED)	Mar - Aug 79
(2)	Procurement Cycle	Sep - Nov 79
(3)	Fabrication of Test Items	Dec 78 - Feb 80
(4)	ED Test	Mar - Jun 80
(5)	IPR	Jul - Aug 80
(6)	Procurement Cycle	Sep - Nov 80
(7)	Fabrication of DT/OT Items	Dec 79 - Mar 81
(8)	DT II - OT II	Apr - Jul 81
(9)	DEVA IPR	Oct 81
(10)	Type Classification	Nov 81

7. Logistics Support Implications. The body armor shall be designed for "repair by replacement." No special tools or test equipment will be required at the organizational/user level and there should be no operator maintenance except normal care and cleaning. Research, development and testing of body armor conducted to date indicates there should be no logistics constraints or special considerations applicable to the design or development of the item.

8. Training Support Implications. The body armor will be used by highly trained EOD personnel; and, due to the simplicity of the system, extensive additional training will not be required. It is essential that the developer furnish a technical manual and training package of practical and instructional media emphasizing the protection

afforded, safety, operational use, care and cleaning of the item. The training package will be developed in the Integrated Technical Documentation and Training (ITDT) format in accordance with one of the three MIL SPEC options currently available and will be available for verification at OT II.

9. Funding.

a. Summary of estimated life cycle costs as expressed in constant and inflated FY 76 dollars ($M - Millions).

	CONSTANT DOLLARS			CONSTANT DOLLARS		
	Low	Most Likely	High	Low	Most Likely	High
RDT&E	0.491	0.546	0.600	0.559	0.621	0.683

b. Quantity/Unit Costs, estimated design to unit flyaway and unit procurement costs expressed in constant FY 76 dollars.

ITEM	QTY	UNIT FLYAWAY	UNIT PROCUREMENT
Body Armor for EOD	150	Estimated unit cost $700/unit	

NOTE 1: Sunk Costs

a. R&D - $0

b. Investment - $0

NOTE 2: Quantity of prototypes - 150

c. Recommend funding profile expressed in constant FY 76 dollars and inflated dollars ($M-Millions).

	CONSTANT DOLLARS				
	FY 77	FY 78	FY 79	FY 80	TOTAL
*Qty	-	50	100	-	150
RDT&E	0.082	0.189	0.249	0.026	0.546

INFLATED DOLLARS

	FY 77	FY 78	FY 79	FY 80	TOTAL
*Qty	-	50	100	-	150
RDT&E	0.093	0.213	0.285	0.029	0.621

NOTE 3: Inflation has been incorporated in accordance with DARCOM directive issued on 14 Dec 76.

*Qty - refers to quantity of major item procured in referenced FY.

ROBERT J. LUNN
Major General, USA
Director of Development
and Engineering

JAMES H. MERRYMAN
Major General, GS
Deputy Chief of Staff
for Combat Developments

APPENDIX B

DESCRIPTIONS AND INSTRUCTIONS FOR GROSS BODY MOBILITY TASKS

1. Walk Forward: Five Steps

a. Materials: Horizontal scale on the floor marked at 1.0 centimeter intervals.

b. Instructions to tester: Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: The distance traveled is measured from the heel of the foot when starting to the toe of the foot taking the fifth step. Four successive trials are administered with 10-second intervals between trials. The score is the mean of the four trials.

c. Instructions to be read to the subject:

(1) Stand erect with your back against the wall and both feet together. You will take five steps forward and try to go as far as possible on each step. Your feet must be kept parallel at all times. You may pause between steps to bring your feet together if you wish. If you lose your balance at any time, you will go back to the wall and start the trial over.

(2) Are there any questions? (Correct the subjects if they are not following instructions.)

Figure B1. Walk Forward (Five Steps).

2. **Walk Backward: Five Steps**

a. **Materials:** Horizontal scale on the floor marked at 1.0 centimeter intervals.

b. **Instructions to tester:** Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: The distance traveled is measured from the toe of the foot when starting to the heel of the foot taking the last step. Four successive trials are administered with 10-second intervals between trials. The score is the mean of the four trials.

c. **Instructions to be read to the subject:**

(1) Stand facing the wall with your feet together. Get as close to the wall as possible. You will take five steps backward and try to go as far as possible on each step. Your feet must be kept parallel at all times. You may pause between steps to bring your feet together if you wish. If you lose your balance at any time, you will go back to the wall and start the trial over.

(2) Are there any questions? (Correct the subjects if they are not following instructions.)

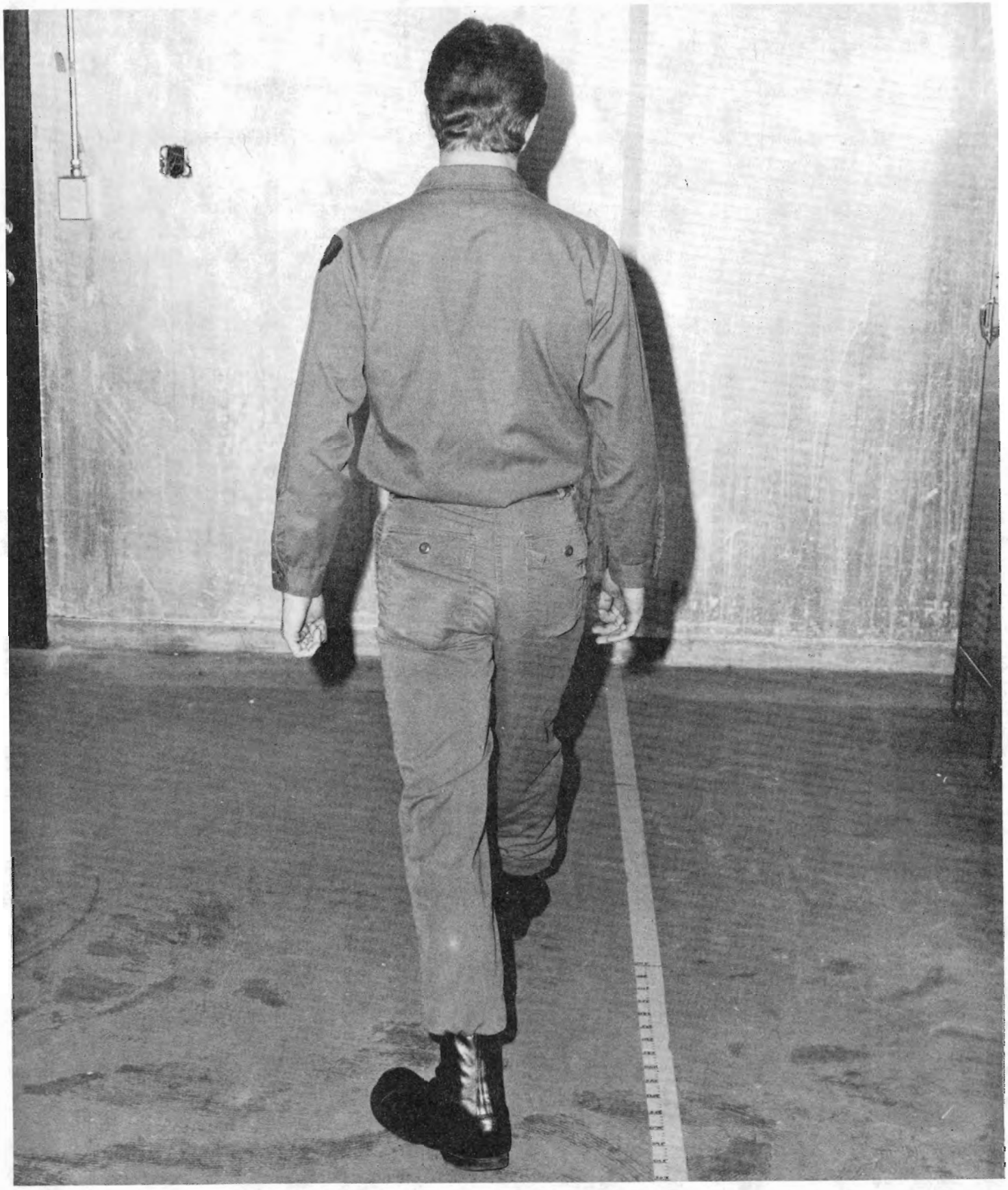

Figure B2. Walk Backward (Five Steps).

3. **Side Step: Five Steps**

a. **Materials:** Horizontal scale on the floor marked at 1.0 centimeter intervals.

b. **Instructions to tester:** Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: The distance traveled is measured from the right side of the right foot before starting to the left side of the left foot after the fifth step. Four successive trials are administered with 10-second intervals between trials. The score is the mean of the four trials.

c. **Instructions to be read to the subject:**

(1) Stand with your right shoulder against the wall. Keep your feet together and get as close to the wall as possible. You will take five steps sidewards, stepping out with the left foot. You will try to go as far as possible on each step. Bring your right foot up to the left one with each step. Be careful not to jump; that is, do not get both feet off the ground at the same time. If you jump, you will go back to the wall and start the trial over.

(2) Are there any questions? (Correct the subjects if they are not following instructions).

Figure B3. Side Step (Five Steps).

4. **Standing Trunk Flexion**

a. **Materials:** A meter stick.

b. **Instructions to tester:** Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: Measure the maximal point to which the subject's fingertips reach when the movement is performed. The meter stick is placed perpendicular to the floor and the distance is measured from the floor to the subject's fingertips. Four successive trials are administered with 15-second intervals between trials. The score is the mean of the four trials.

c. **Instructions to be read to the subject:**

(1) Stand erect with your feet parallel, about four inches apart. Keep your knees stiff and do two preliminary toe touches; that is, bend at the waist and reach down as far as possible each time. Do a third toe touch, keeping your hands together, and holding that position for a few seconds.

(2) Are there any questions? (Correct the subjects if they are not following instructions).

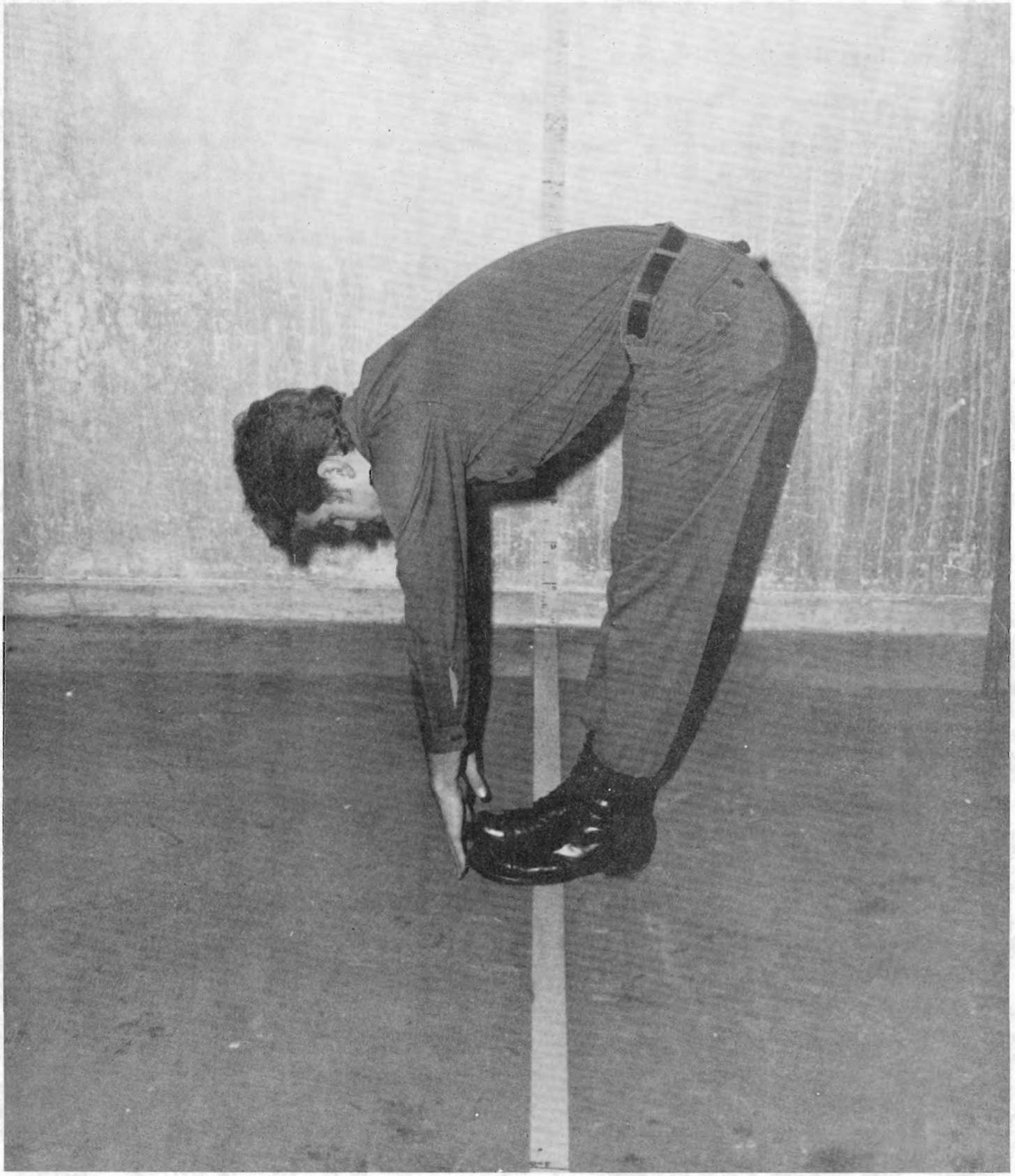

Figure B4. Standing Trunk Flexion.

5. Head Rotation

a. **Materials:** Goniometer and straight-backed chair.

b. **Instructions to tester:** Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: The goniometer is placed on the cranial surface (top) of the head and is zeroed when the subject has rotated his head as far as possible to the left. It is read when the subject has rotated his head as far as possible to the right. Four trials are given with 15-second intervals between trials. The score is the mean of the four trials.

c. **Instructions to be read to the subject:**

(1) Stand straight and then bend at the waist until your chest and head are parallel to the floor. Grab the seat of the chair to hold yourself that way.

(2) Turn your head to the left, and then hold it. (Set the goniometer to zero.) Now turn your head to the right and hold it.

(3) Are there any questions? (Correct the subjects if they are not following instructions.)

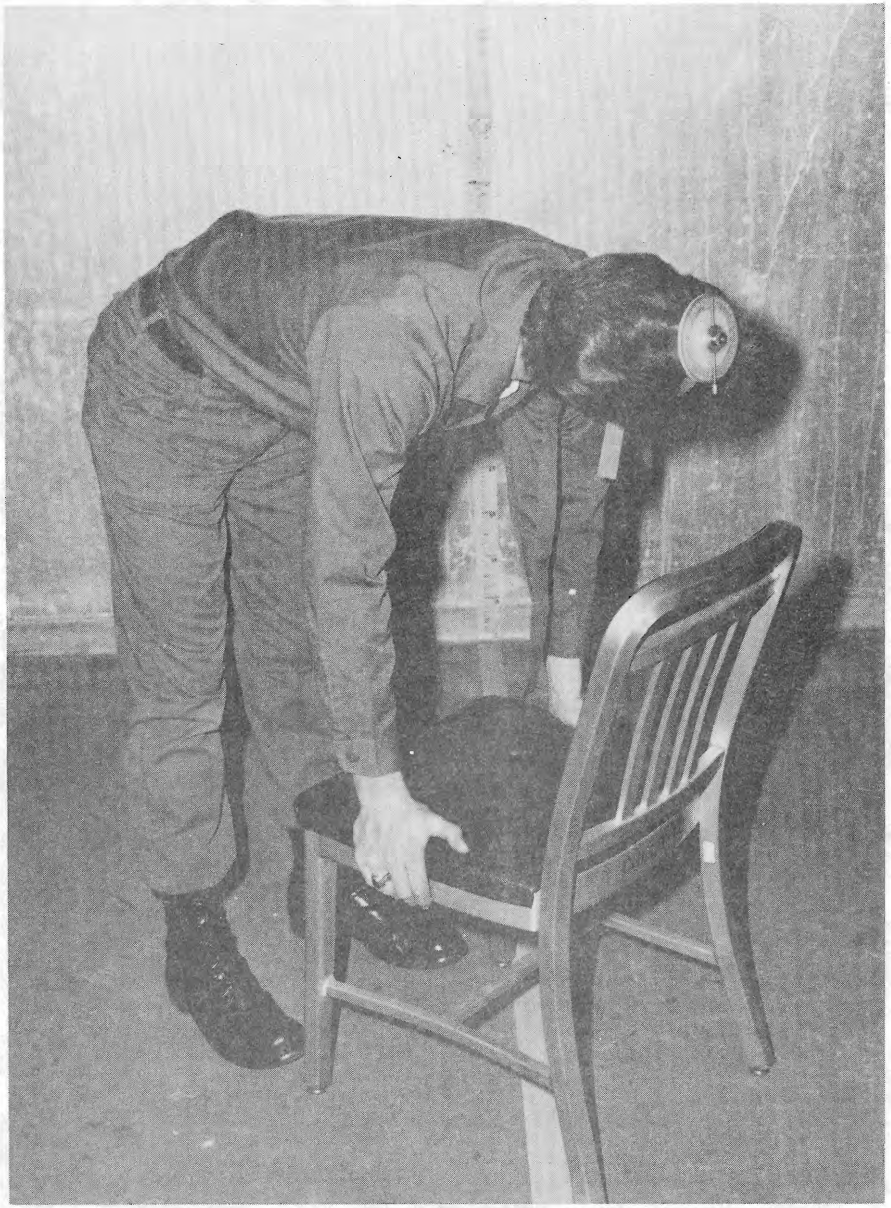

Figure B5a. Head Rotation: Initial position, goniometer set to zero.

Figure B5b. Head Rotation: Final position, goniometer ready to be read.

6. Ventral-Dorsal Head Flexion

a. **Materials:** Goniometer and straight-back chair.

b. **Instructions to tester:** Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: The goniometer is placed on the right lateral surface of the head and is zeroed when the subject's head is forward and down in a ventral position. The shoulders remain against the back of the chair. The head is then tilted as far back as possible (dorsal position) and the displacement of the head from the zero position is read in degrees. Four trials are given with 15-second intervals between trials. The score is the mean of the four trials.

c. **Instructions to be read to the subject:**

(1) Sit upright in the chair with your hands clasped behind the chair. Try not to move your chest or shoulders.

(2) When I tell you, bend your head as far down as possible without moving your chest or shoulders. Hold this position for five seconds. (Set the goniometer to zero.)

(3) Now bend your head as far back as possible without moving your shoulders or chest. Hold this position for five seconds.

(4) Are there any questions? (Correct the subjects if they are not following instructions.)

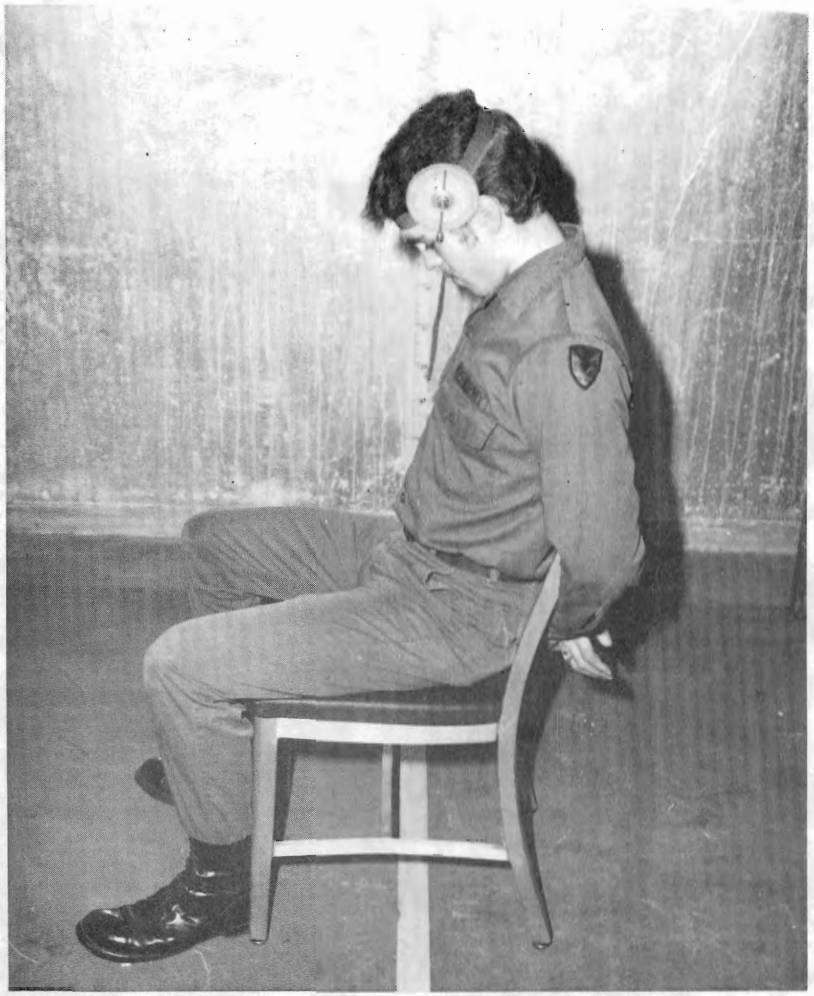

Figure B6a. Ventral-Dorsal Head Flexion: Initial position, goniometer set to zero.

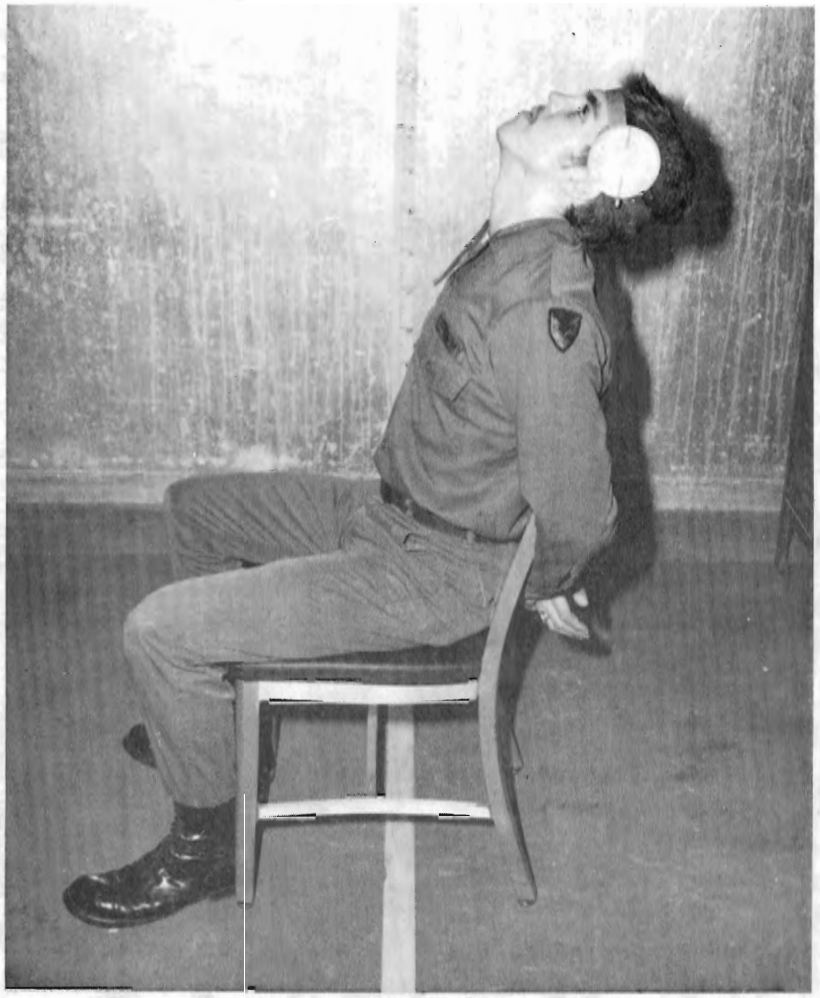

Figure B6b. Ventral-Dorsal Head Flexion: Final position, goniometer ready to be read

7. Upper Arm Abduction

a. **Materials:** Goniometer.

b. **Instructions to tester:** Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: Place the goniometer on the right arm just above the elbow with the dial on the posterior side of the arm. Set the goniometer to zero. Be sure that the subject is standing with toes, abdomen, sternum, and nose against the projecting corner of a wall. Watch for contact with the wall, extension of the back, arm rotation, elbow flexion, and movement out of the frontal plane. The reading is taken at the point where a deviation occurs or no further movement is possible. Four trials are given with 15-second intervals between trials. The score is the mean of the four trials.

c. **Instructions to be read to the subject:**

(1) Start facing the corner with toes, abdomen, sternum, and nose against the corner of the wall, arms hanging at your sides, palms facing in toward the body. (Set the goniometer to zero.)

(2) Raise both arms sideward and upward as far as possible while maintaining the contact with the wall.

(3) Are there any questions? (Correct the subjects if they are not following the instructions.)

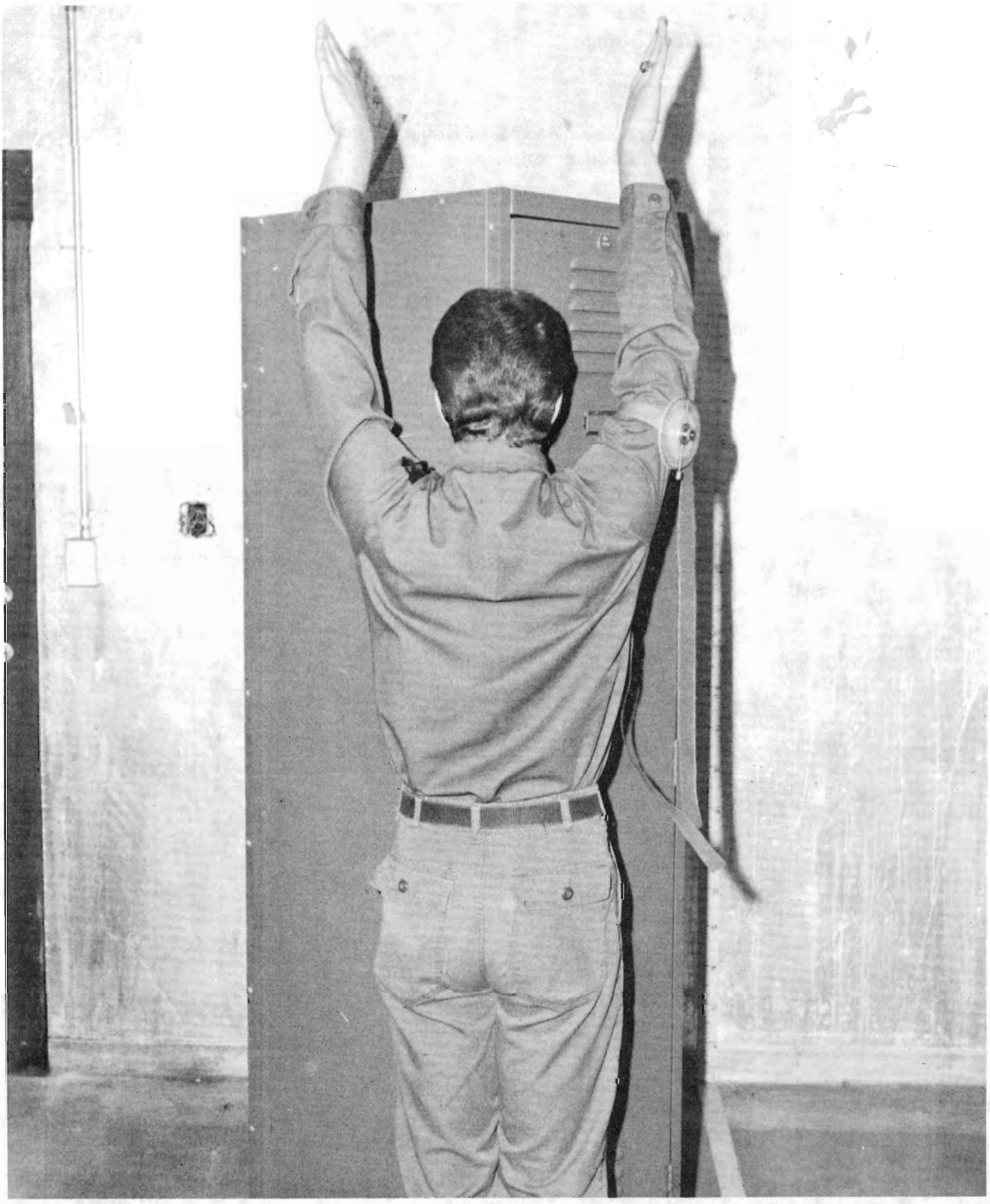

Figure B7. Upper Arm Abduction.

8. Upper Arm Forward Extension

a. **Materials:** Goniometer.

b. **Instructions to the tester:** Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: Place the goniometer on the right arm just above the elbow with the dial on the lateral surface. Be sure that the subject is standing with his arm against his side, elbow stiff and the arm perpendicular to the floor. Set the goniometer to zero. Read the goniometer when the arm is raised as far forward and up as possible. The elbow is kept stiff and the arm parallel to the median plane. The trunk is maintained erect. There are four trials with 15-second intervals between trials. The score is the mean of the four trials.

c. **Instructions to be read to the subject:**

(1) Stand facing the wall but not quite touching it. Your right shoulder and arm should be just past the edge of the doorway.

(2) Place your right arm against your side with the elbow stiff and the arm straight down. (Set goniometer to zero.)

(3) Now raise your entire arm forward and up as far as possible. Keep your elbow stiff and stand up straight.

(4) Are there any questions? (Correct the subjects if they are not following instructions.)

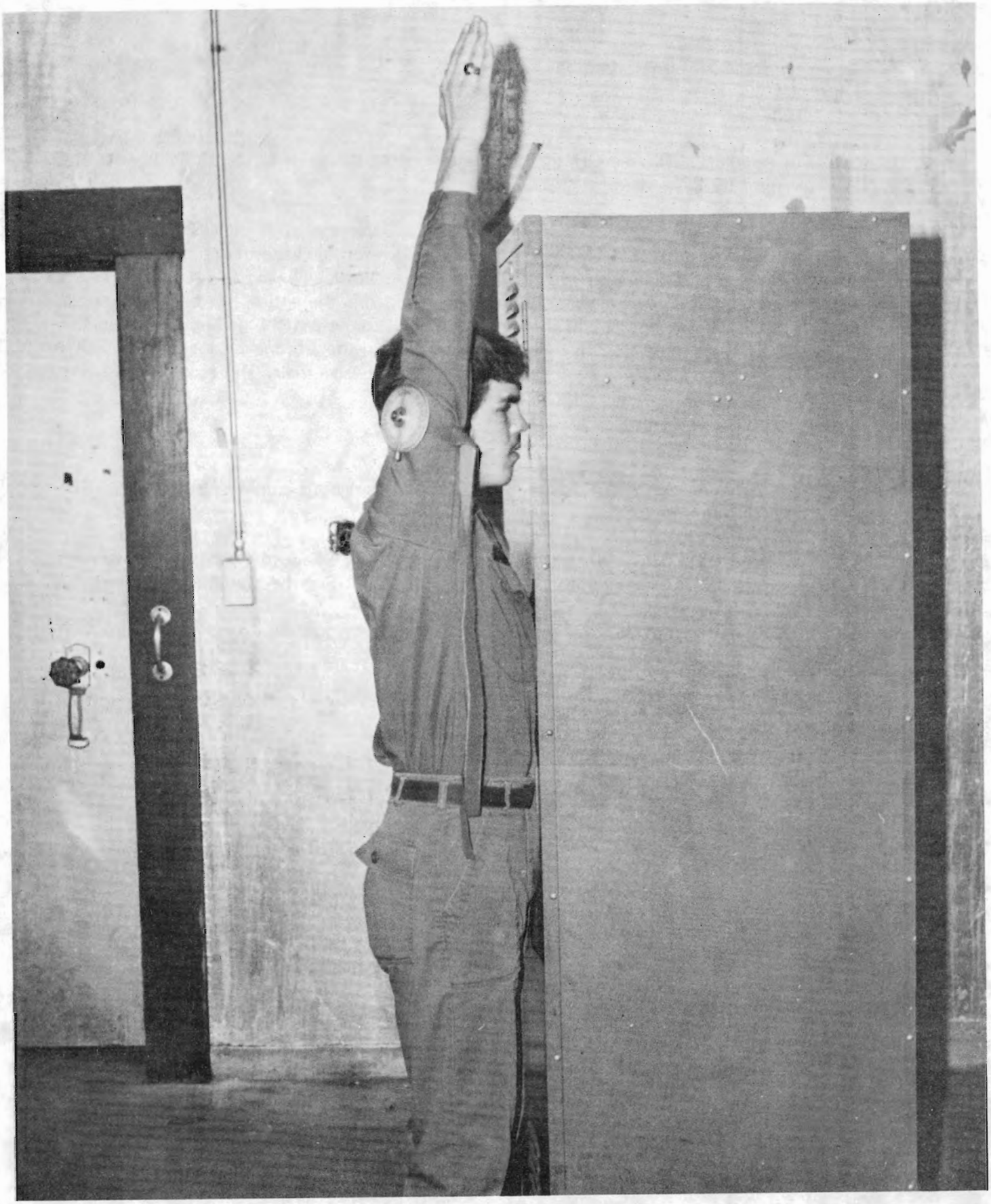

Figure B8. Upper Arm Forward Extension.

9. **Upper Arm Backward Extension**

a. **Materials:** Goniometer.

b. **Instructions to tester:** Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: The subject stands erect with the back against a wall. The entire arm, elbow stiff, is rotated until the palm of the hand faces outward and the thumb points dorsally. The goniometer is placed on the right arm just above the elbow and is set to zero when the arm is perpendicular to the floor. The subject extends the entire arm backward as far as possible while keeping the elbow stiff and the palm out. Read the goniometer when the limit of motion is reached, when the elbow bends, or when the arm moves out of the medial plane. There are four trials with 15-second intervals between trials. The score is the mean of the four trials.

c. **Instructions to be read to the subject:**

(1) Stand with your back to the wall. Your right shoulder and arm should be just past the edge of the doorway.

(2) Place your right arm against your side with the elbow stiff and the arm straight down. Rotate your arm until your palm faces outward. (Set the goniometer to zero.)

(3) Now raise your entire arm backward as far as possible. Keep your elbow stiff and your palm out.

(4) Are there any questions? (Correct the subjects if they are not following instructions.)

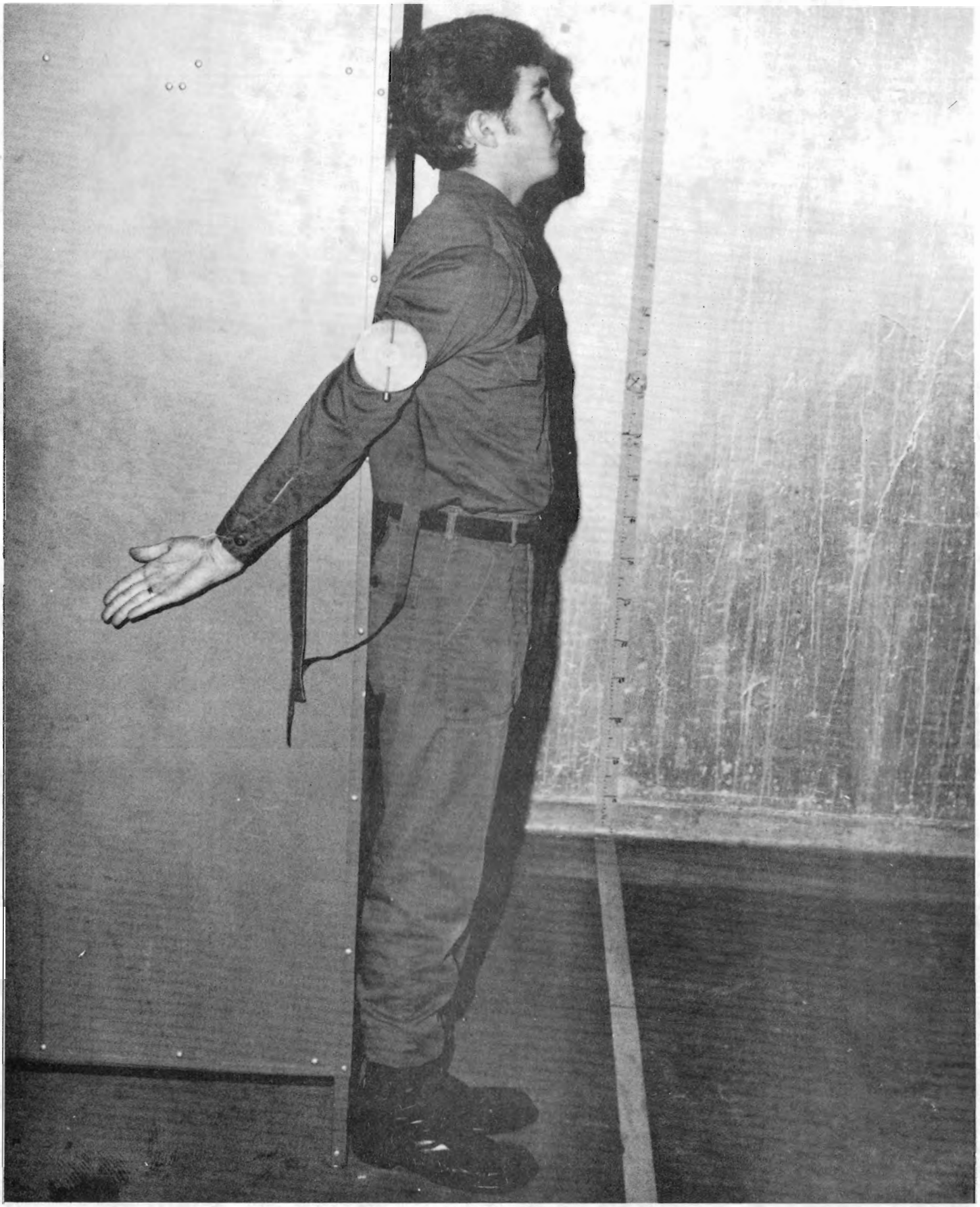

Figure B9. Upper Arm Backward Extension.

10. Upper Leg Abduction

a. Materials: Goniometer.

b. Instructions to tester: Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: Place the goniometer on the right leg just above the knee with the dial on the posterior side of the leg. Be sure that the subject is standing erect, feet together, and facing an upright support. The subject grasps the support firmly with both hands. Set the goniometer to zero. Watch for bending of the trunk and leg rotation. The reading is taken at the point where a deviation occurs or no further movement is possible. Four trials are given with 15-second intervals between trials. The score is the mean of the four trials.

c. Instructions to be read to the subject:

(1) Start facing this support and about one foot from it. Stand erect with your feet together and grasp the support with both hands. (Set the goniometer to zero.)

(2) Raise your right leg sideward and up as far as possible being careful not to bend your trunk or rotate your leg. Also, keep your knee stiff.

(3) Are there any questions? (Correct the subjects if they are not following instructions.)

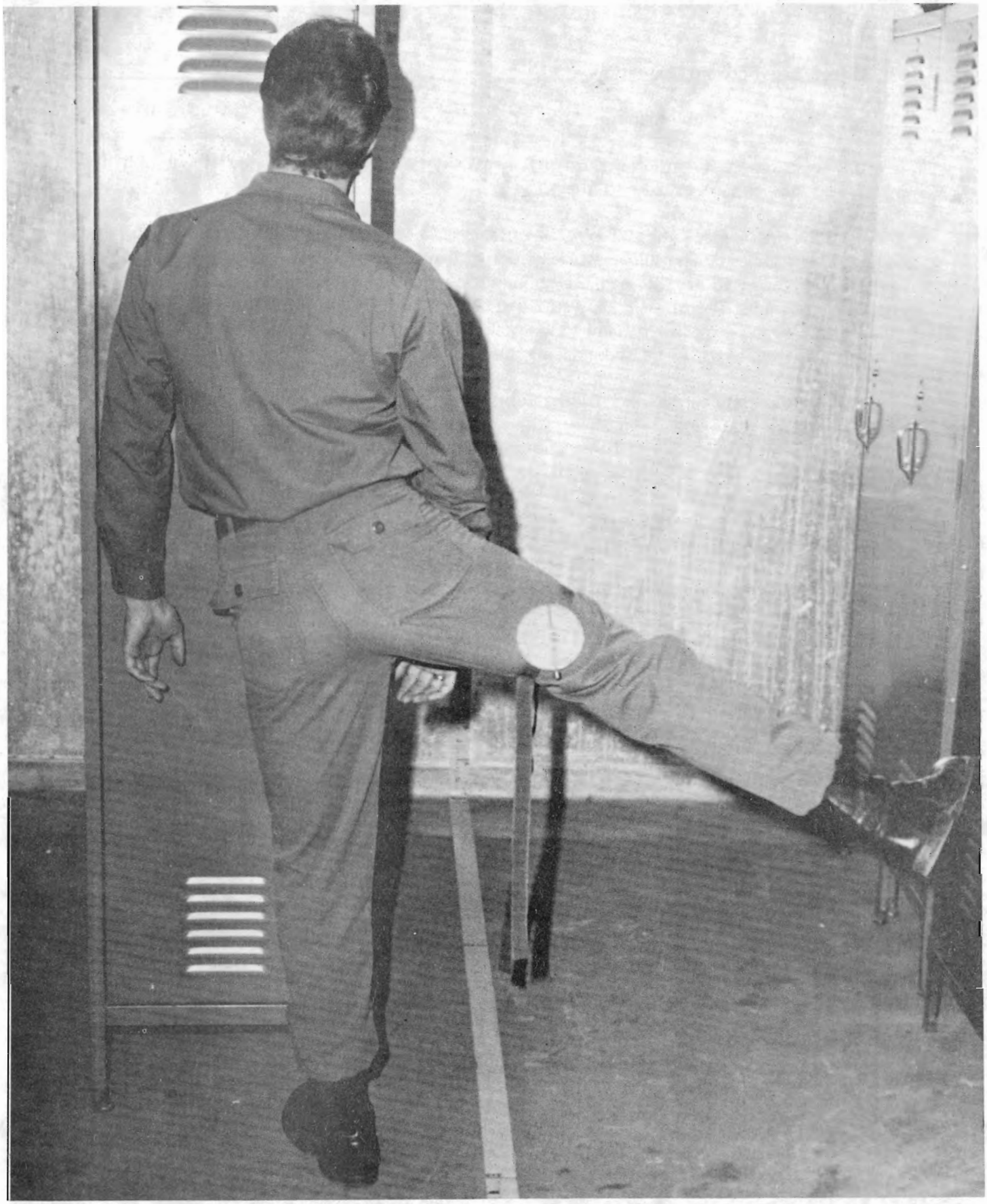

Figure B10. Upper Leg Abduction.

11. Upper Leg Forward Extension

a. **Materials:** Goniometer.

b. **Instructions to tester:** Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: Place the goniometer on the right leg just above the knee with the dial on the lateral surface. The subject stands erect with the back against a wall and feet together. Set the goniometer to zero. Read the goniometer when the right leg is raised as far forward and up as possible. The knee is kept stiff and the back is kept against the wall. An upright support is grasped with the left hand to maintain balance. There are four trials with 15-second intervals between trials. The score is the mean of the four trials.

c. **Instructions to be read to the subject:**

(1) Stand erect with your feet together and your back against this wall. Grasp the support with your left hand. (Set the goniometer to zero.)

(2) Raise your leg forward and up as far as possible. Keep your knees stiff and your back against the wall.

(3) Are there any questions? (Correct the subjects if they are not following instructions.)

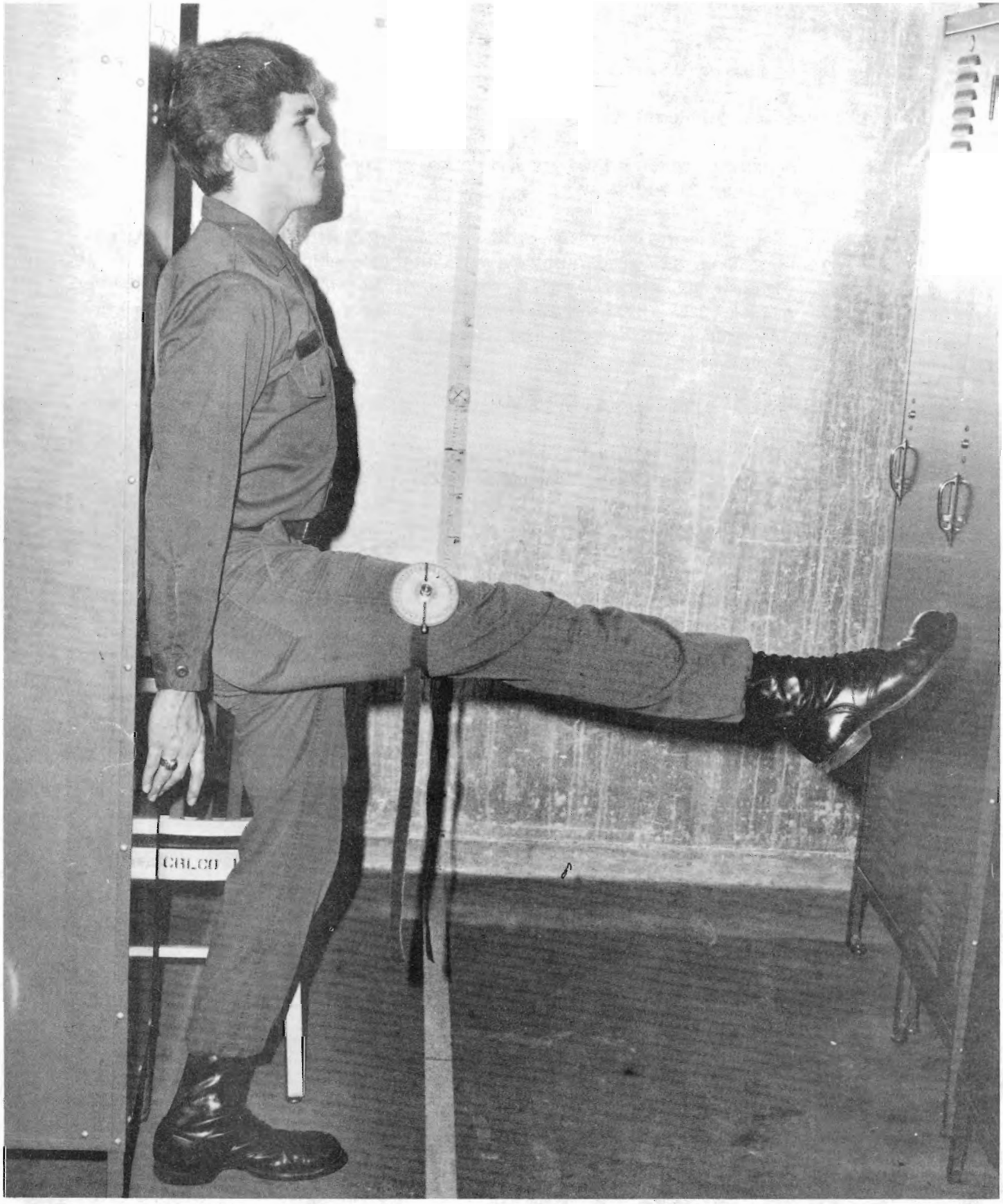

Figure B11. Upper Leg Forward Extension.

12. Upper Leg Backward Extension

a. **Materials:** Goniometer.

b. **Instructions to tester:** Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: Place the goniometer on the lateral surface of the right leg just above the knee. The subject stands facing and touching a wall with the right hip and leg partially extended beyond it. The right hip is pressed against the edge of the wall and the feet are together. Set the goniometer to zero. Read the goniometer when the right leg is raised as far backward as possible. There are four trials with 15-second intervals between trials. The score is the mean of the four trials.

c. **Instructions to be read to the subject:**

(1) Stand facing this wall with your right foot just beyond it and your right hip just touching its edge. (Set the goniometer to zero.)

(2) Now move your right leg as far backward as possible. Keep up against the wall at all times. Hold that position.

(3) Are there any questions? (Correct the subjects if they are not following instructions.)

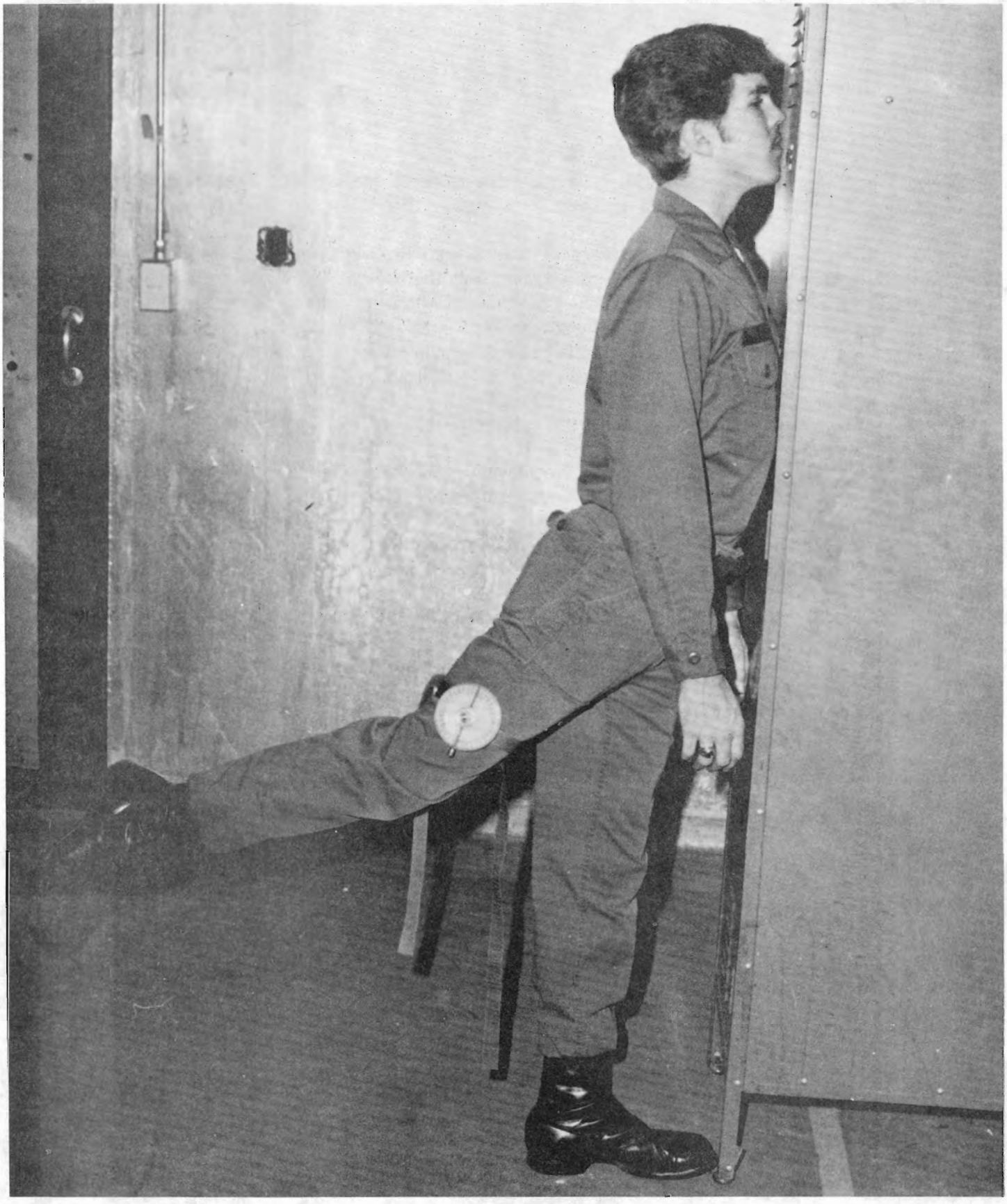

Figure B12. Upper Leg Backward Extension.

13. Upper Leg Flexion

a. **Materials:** Goniometer.

b. **Instructions to tester:** Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: Place the goniometer on the right leg just above the knee with the dial on the lateral surface. The subject stands erect with the back against a wall and feet together. Set the goniometer to zero. Read the goniometer when the right upper leg is raised as far up as possible. The right leg is allowed to bend freely at the knee. An upright support is grasped with the left hand to maintain balance. There are four trials with 15-second intervals between trials. The score is the mean of the four trials.

c. **Instructions to be read to the subject:**

(1) Stand erect with your feet together and your back against this wall. Grasp the support with the left hand. (Set the goniometer to zero.)

(2) Raise your upper leg up as far as possible. Let your lower leg bend freely at the knee. Keep your left knee stiff and your back against the wall.

(3) Are there any questions? (Correct the subjects if they are not following instructions.)

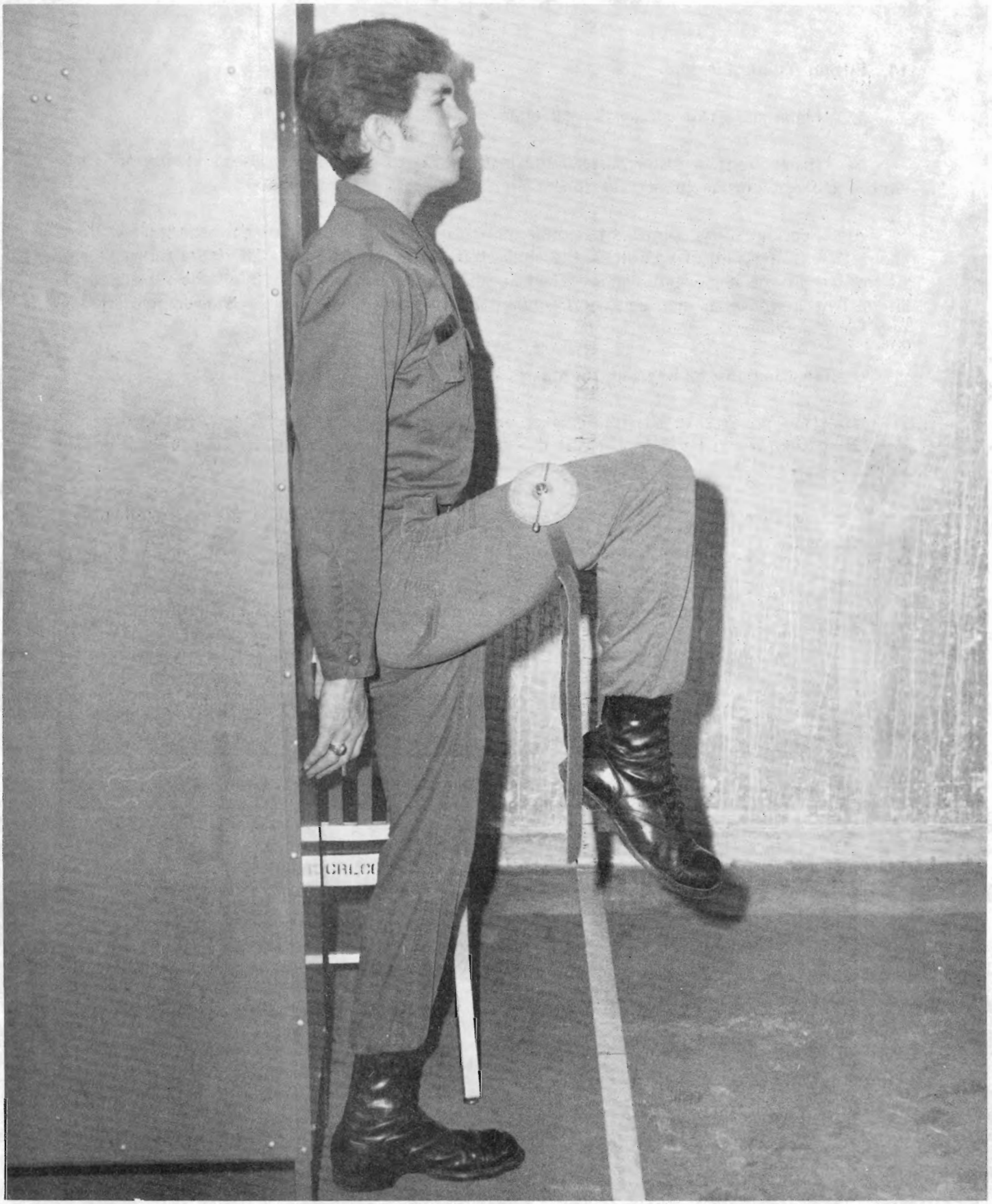

Figure B13. Upper Leg Flexion.

14. Sitting Trunk Flexion

a. Materials: One straight–back chair.

b. Instructions to tester: Read the instructions to the subject. Read them word for word. Do not change or add to them.

c. Scoring: The subject's performance is rated: "O" if the subject cannot sit in the chair; "1" if the subject can sit in the chair, but cannot sit upright; "2" if the subject can sit upright in the chair, but cannot bend forward at the waist; and "3" if the subject can sit upright in the chair and can bend forward at the waist. The subject is given two trials, one for practice and one for record.

d. Instructions to be read to the subject:

(1) You are to sit in the chair and assume an upright position. After you have done that, you are to bend forward at the waist as far as you can. Keep your arms at your sides.

(2) Are there any questions? (Correct the subjects if they are not following instructions.)

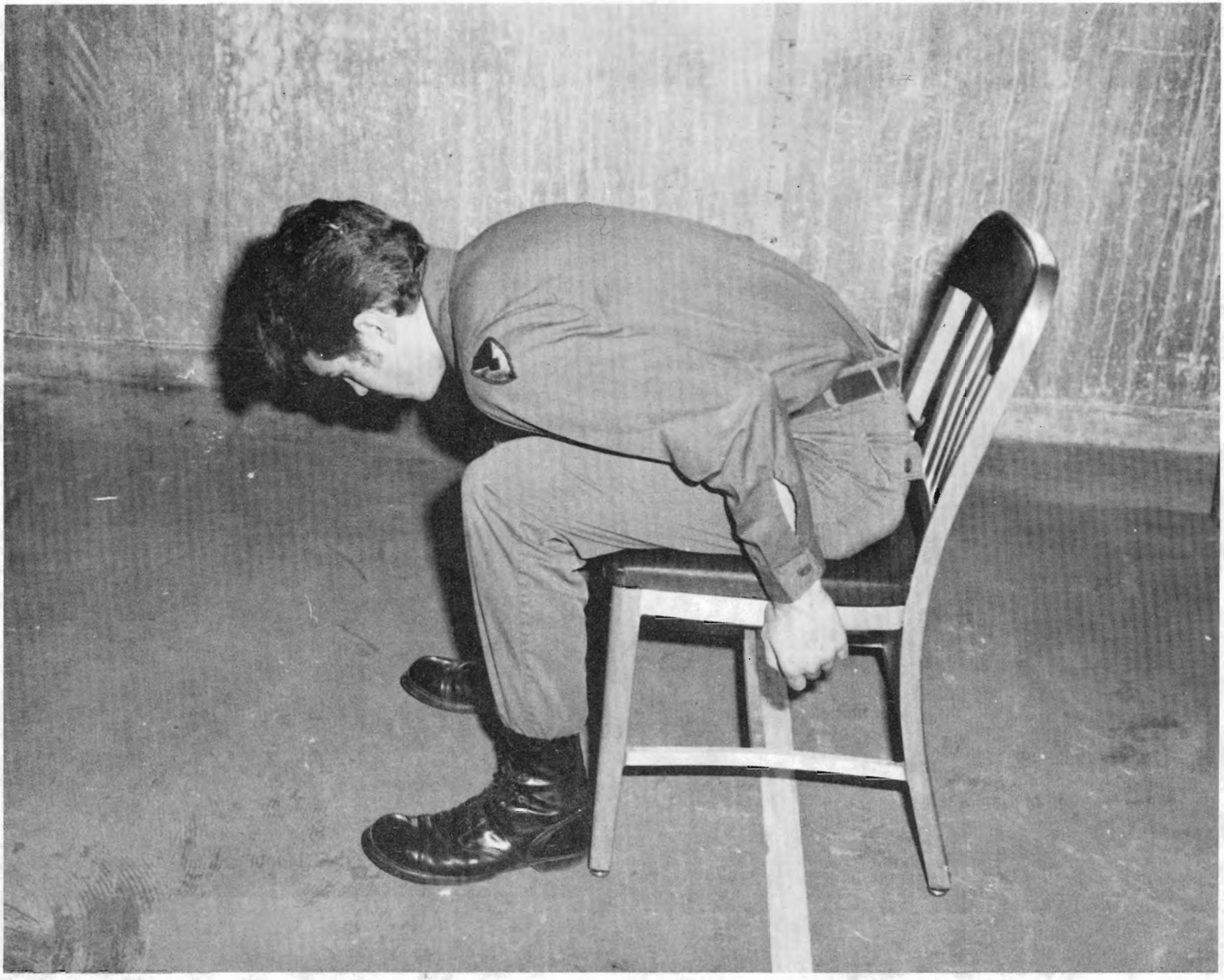

Figure B14. Sitting Trunk Flexion.

15. Kneel and Rise

a. **Materials:** One straight–back chair.

b. **Instructions to tester:** Read the instructions to the subject. Read them word for word. Do not change or add to them.

c. **Scoring:** The subject's performance is rated: "0" if the subject cannot kneel on both knees; "1" if the subject cannot rise from the kneeling position without the aid of the experimenter; "2" if the subject can rise from the kneeling position, but needs to grasp an inanimate object (railing, chair, table, etc.) for support; and "3" if the subject can rise from the kneeling position without any help at all. The subject is given two trials, one for practice and one for record.

d. **Instructions to be read to the subject:**

(1) Assume a standing position. From this position, you will get down on both knees and then rise to the standing position again. Try to rise from the kneeling position without touching anything with your hands or arms. If you need help, you may grasp the chair or I will give you a hand. (If the subject requests help to rise, the tester offers the chair before offering a hand).

(2) Are there any questions? (Correct the subjects if they are not following instructions.)

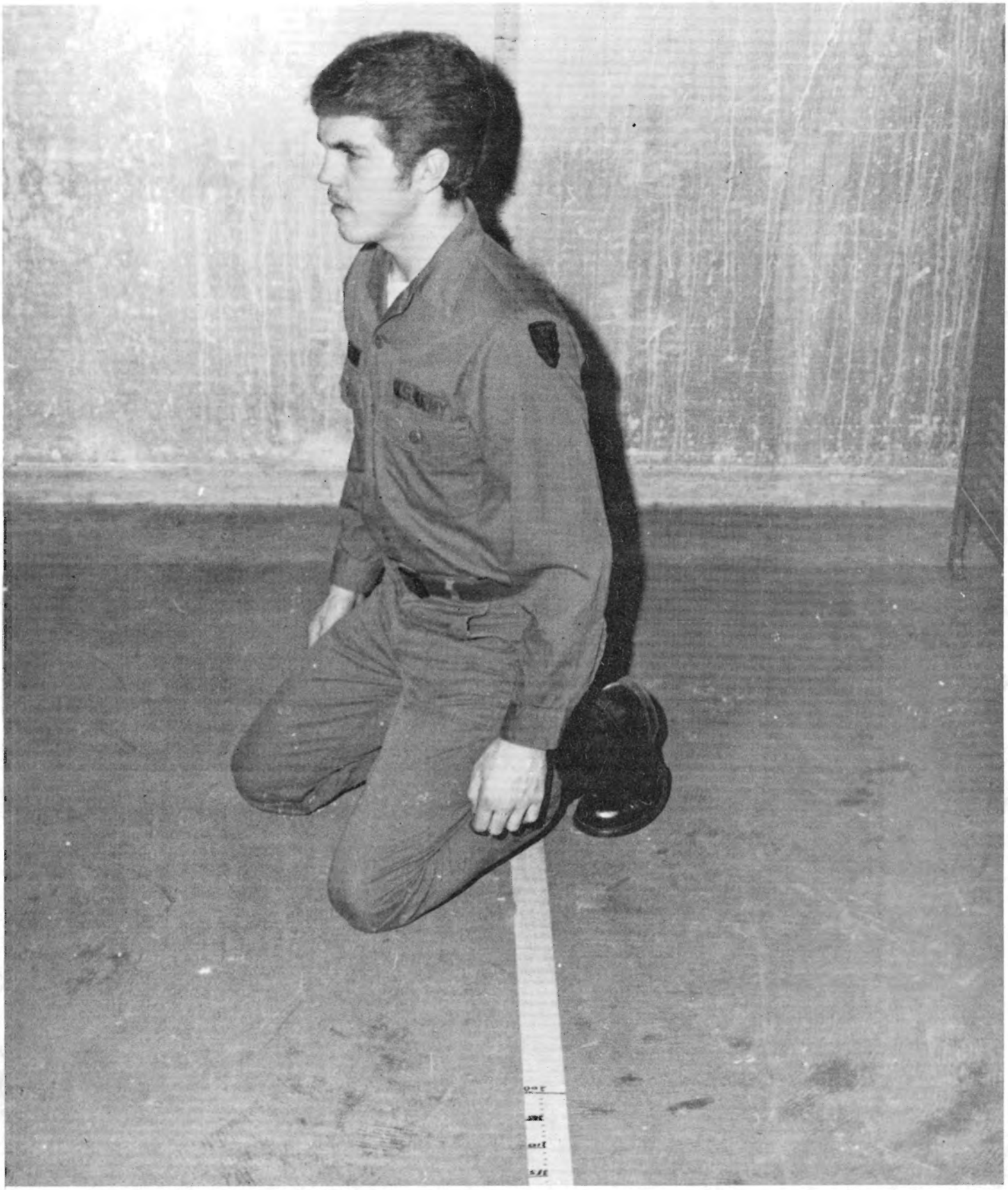

Figure B15. Kneel-and-Rise.

APPENDIX C

DESCRIPTIONS AND INSTRUCTIONS

FOR PSYCHOMOTOR TASKS

1. O'Connor Fine Finger Dexterity Task

a. **Materials:** Pegboard equipped with pins and located on a table. The pins are 2.5 cm long and 0.1 cm in diameter. Each hole in the pegboard is 0.5 cm in diameter.

b. **Instructions to tester:** Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: The time required to place three pins in each of 20 holes is the subject's score. The subject stands to do the task and can use only one hand.

c. **Instructions to be read to the subject:**

(1) Begin with your preferred hand on the table alongside the board.

(2) On the "Go" signal, pick up as many as three pins with your preferred hand and place them in a hole on the board. Continue picking up and dropping the pins into the holes with your preferred hand until there are three pins in each hole.

(3) Your score is the time required to put three pins in every hole.

(4) Are there any questions? Ready? Go. (Correct the subjects if they are not following instructions.)

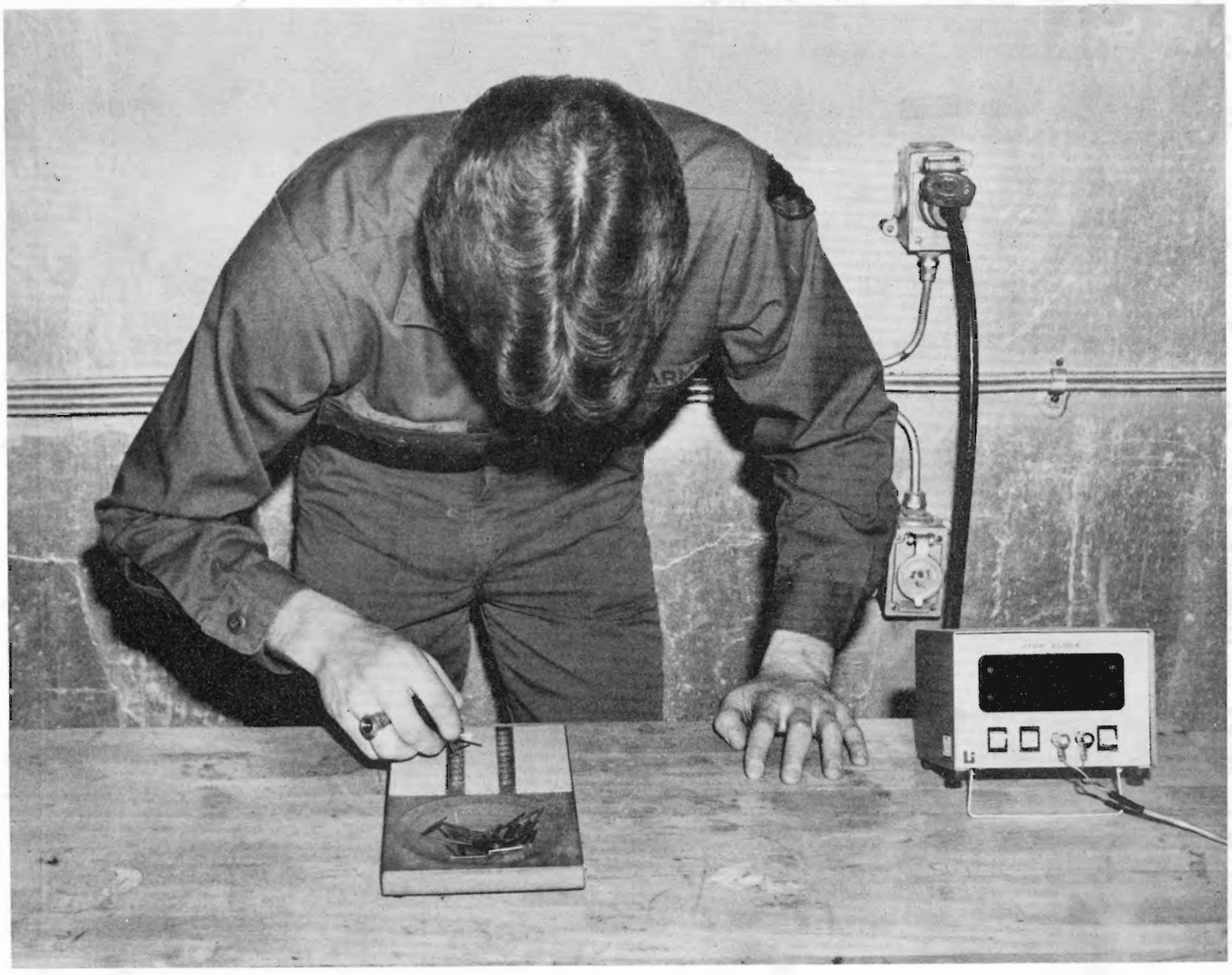

Figure C1. O'Connor Fine Finger Dexterity Task.

2. **Cord and Cylinder Manipulation Task**

a. **Materials:** Ten large and one small loop of 0.24 cm woven nylon cord attached at equal intervals to a flexible webbing base with a hook at the far end, and 10, 1.27 cm plastic cylinders with a 0.95 cm bore.

b. **Instructions to tester:** Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: The time required to string the 10 cylinders to the 10 loops is the subject's score. The subject stands to do the task and uses both hands.

c. **Instructions to be read to the subject:**

(1) Begin with both hands on the table alongside the webbing.

(2) On the "Go" signal, grasp the nearest loop and elongate it until the sides are brought together. Insert the doubled end through a cylinder, and then open it to form a smaller loop. Elongate the next loop, pass it through the first loop, and through a cylinder. Continue this, picking up one cylinder at a time, until the 10 loops form a chain that has one cylinder mounted on each loop. Insert the small, final loop through the tenth loop, and place it over the hook. This completes the task.

(3) Your score is the time required to string the 10 cylinders to the 10 loops.

(4) Are there any questions? Ready? Go. (Correct the subjects if they are not following instructions.)

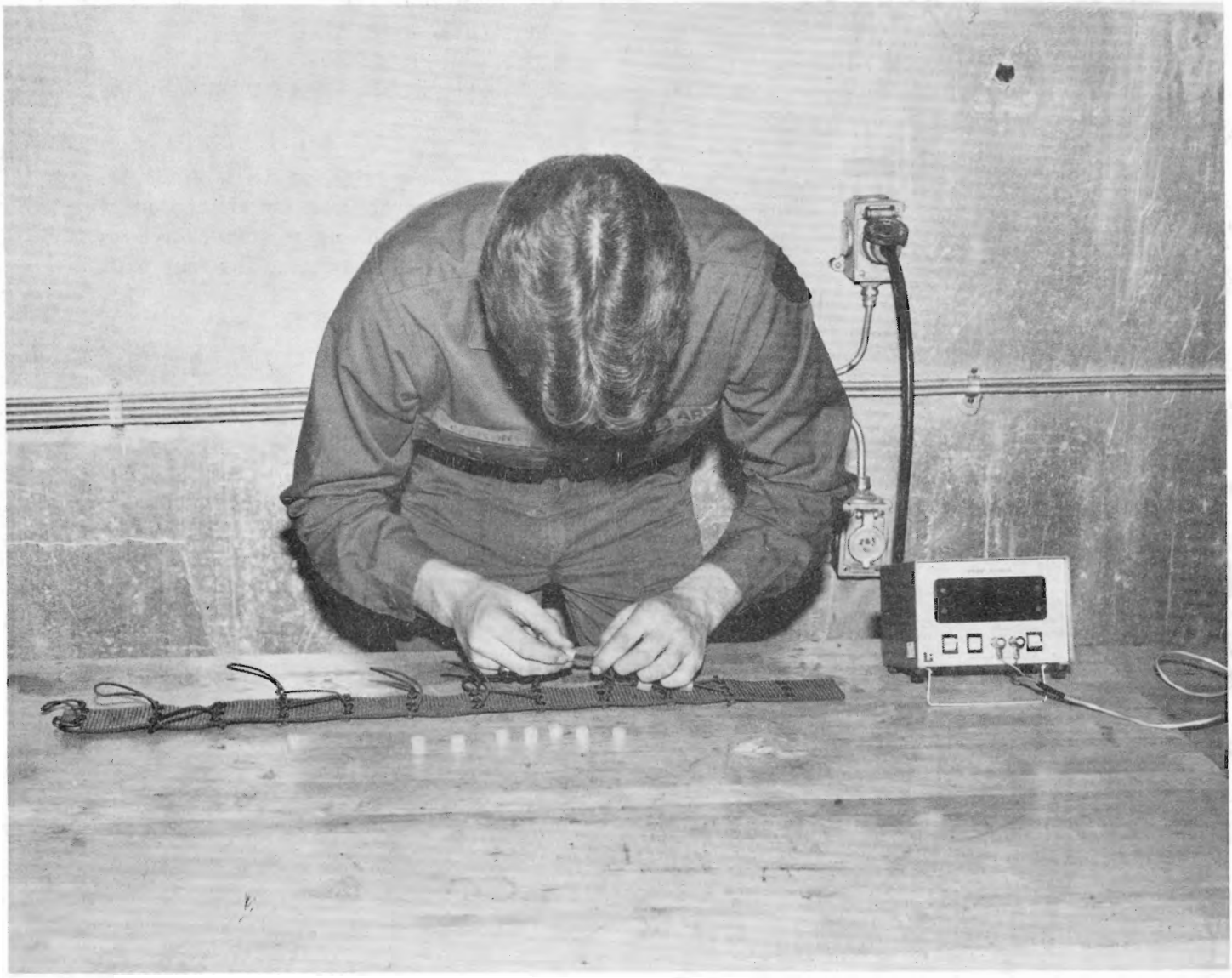

Figure C2. Cord and Cylinder Manipulation Task.

3. Pursuit Rotor Task

a. **Materials:** A turntable, 25.5 cm in diameter, with a circular target disc, 1.9 cm in diameter, embedded in the turntable surface, and a stylus with a tip 0.3 cm in diameter. The Lafayette Rotary Pursuit Model 30012 was used in this study.

b. **Instructions to tester:** Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: The subject stands and holds the stylus in the preferred hand. While the turntable is revolving at 60 revolutions per minute, the subject is to track the moving target by keeping the stylus in contact with the target disc. The score is the total number of seconds during four, 30–second trials that the stylus is in contact with the target. The four trials are given with a 30–second interval between each trial.

c. **Instructions to be read to the subject:**

(1) Hold the stylus in your preferred hand. Place the tip of the stylus on the target and move the stylus in order to keep it in contact with the target.

(2) Your score is the total amount of time that you can keep the stylus on the target during the four, 30–second trials.

(3) The trial will start when the turntable begins to move. The trial will stop when the turntable stops moving.

(4) Are there any questions?

(5) Begin tracking as soon as the turntable moves.

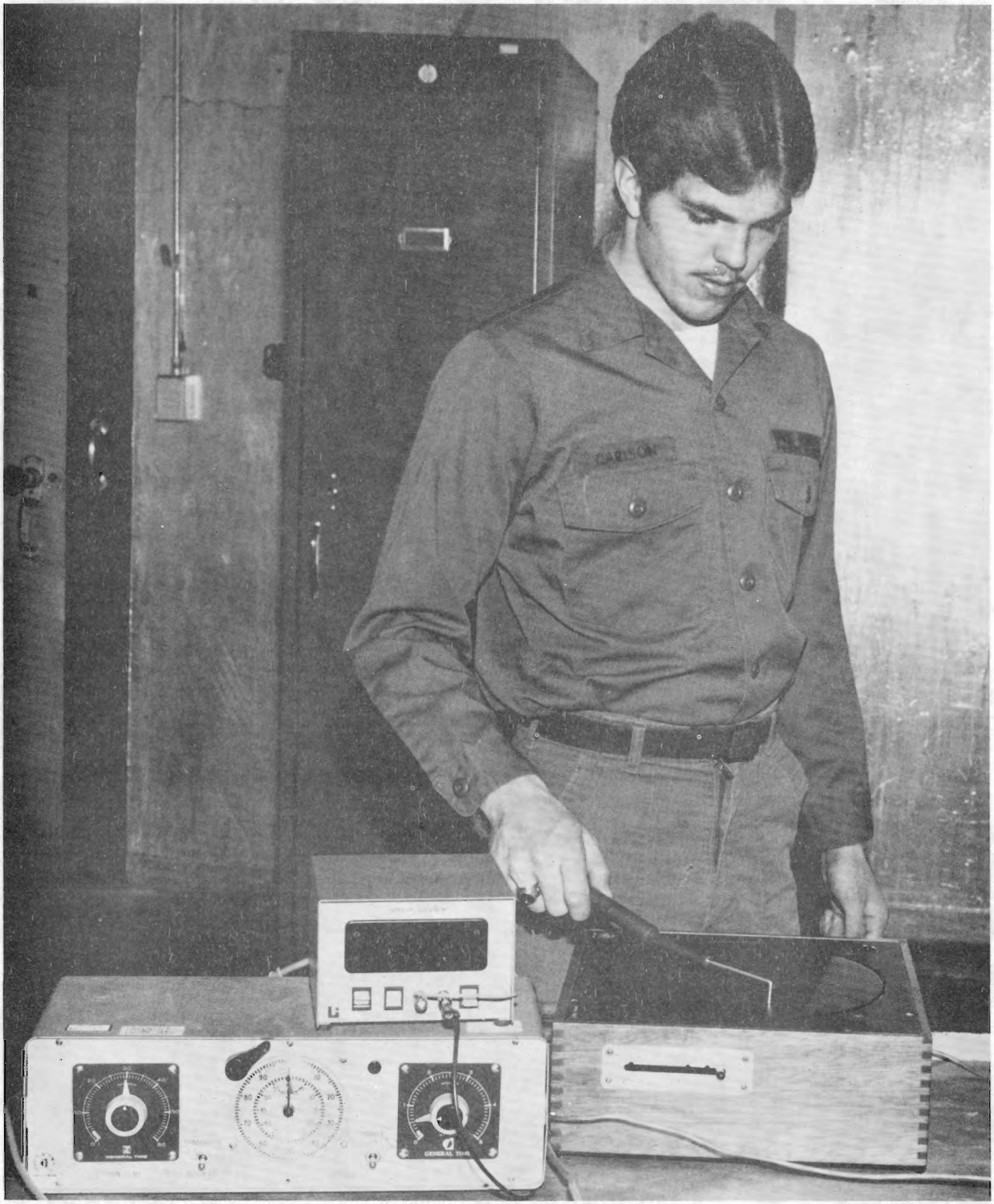

Figure C3. Pursuit Rotor Task.

APPENDIX D

MODIFIED RHYME TEST: INSTRUCTIONS TO LISTENER, LISTENER'S ANSWER SHEETS, TALKER'S LISTS (PRACTICE), AND TALKER'S LISTS (TEST)

MODIFIED RHYME TEST

INSTRUCTIONS

You are going to hear some one syllable words. Each word will be presented in a sentence which will tell you its item number. For example:

Number one is tree.

Number two is mile.

The word presented will be one of six words which are printed on your answer sheet for that particular item. Your job is to identify the word presented to you by drawing a line through the word you hear. For example:

Number three is tow.

3.	ROW	~~TOW~~	LOW
	MOW	SOW	BOW

Some words will be easier to hear than others. If you are not sure what the word is, guess. Always draw a line through one of the six words for each item.

If you have any questions, ask the person running the test.

MODIFIED RHYME TEST

LISTENER'S ANSWER SHEET

FORM 1

INSTRUCTIONS: Draw a line through the word you hear.

1.	PACK	PAD	PAN
	PASS	PAT	PATH

2.	BANG	FANG	GANG
	HANG	RANG	SANG

3.	BIT	FIT	HIT
	KIT	SIT	WIT

4.	PUB	PUCK	PUFF
	PUN	PUP	PUS

5.	GOT	HOT	LOT
	NOT	POT	TOT

6.	DUB	DUCK	DUD
	DUG	DUN	DUNG

7.	FIB	FIG	FILL
	FIN	FIT	FIZZ

8.	LACE	LAKE	LAME
	LANE	LATE	LAY

9.	BALE	GALE	MALE
	PALE	SALE	TALE

10.	SEED	SEEK	SEEM
	SEEN	SEEP	SEETHE

MODIFIED RHYME TEST

LISTENER'S ANSWER SHEET

FORM 1

INSTRUCTIONS: Draw a line through the word you hear.

11.	DIN	FIN	PIN
	SIN	TIN	WIN

12.	RACE	RAKE	RATE
	RAVE	RAY	RAZE

13.	BENT	DENT	RENT
	SENT	TENT	WENT

14.	SICK	SILL	SIN
	SING	SIP	SIT

15.	CAME	FAME	GAME
	NAME	SAME	TAME

16.	DID	DIG	DILL
	DIM	DIN	DIP

17.	DIP	HIP	LIP
	RIP	SIP	TIP

18.	PEACE	PEACH	PEAK
	PEAL	PEAS	PEAT

19.	JAW	LAW	PAW
	RAW	SAW	THAW

20.	BUST	DUST	GUST
	JUST	MUST	RUST

MODIFIED RHYME TEST

LISTENER'S ANSWER SHEET

FORM 1

INSTRUCTIONS: Draw a line through the word you hear.

21.	BEACH	BEAD	BEAK
	BEAM	BEAN	BEAT

22.	BOOK	COOK	HOOK
	LOOK	SHOOK	TOOK

23.	MAD	MAN	MAP
	MASS	MAT	MATH

24.	BEST	NEST	REST
	TEST	VEST	WEST

25.	COP	HOP	MOP
	POP	SHOP	TOP

26.	PICK	PIG	PILL
	PIN	PIP	PIT

27.	BOIL	COIL	FOIL
	OIL	SOIL	TOIL

28.	BUCK	BUFF	BUG
	BUN	BUS	BUT

29.	SUB	SUD	SUM
	SUN	SUNG	SUP

30.	TAB	TACK	TAM
	TAN	TANG	TAP

MODIFIED RHYME TEST

LISTENER'S ANSWER SHEET

FORM 1

INSTRUCTIONS: Draw a line through the word you hear.

31.	TEACH	TEAK	TEAL
	TEAM	TEAR	TEASE

32.	BILL	FILL	HILL
	KILL	TILL	WILL

33.	BED	FED	LED
	RED	SHED	WED

34.	COLD	FOLD	GOLD
	HOLD	SOLD	TOLD

35.	SAFE	SAKE	SALE
	SAME	SANE	SAVE

36.	PACE	PAGE	PALE
	PANE	PAVE	PAY

37.	EEL	FEEL	HEEL
	KEEL	PEEL	REEL

38.	BIG	DIG	FIG
	PIG	RIG	WIG

39.	HEAL	HEAP	HEAR
	HEAT	HEATH	HEAVE

40.	CAKE	CAME	CANE
	CAPE	CASE	CAVE

MODIFIED RHYME TEST

LISTENER'S ANSWER SHEET

FORM 1

INSTRUCTIONS: Draw a line through the word you hear.

41.	KICK	LICK	PICK
	SICK	TICK	WICK

42.	BACK	BAD	BAN
	BASS	BAT	BATH

43.	CUB	CUD	CUFF
	CUP	CUSS	CUT

44.	BARK	DARK	HARK
	LARK	MARK	PARK

45.	DEN	HEN	MEN
	PEN	TEN	THEN

46.	DAY	GAY	MAY
	PAY	SAY	WAY

47.	SACK	SAD	SAG
	SAP	SASS	SAT

48.	KICK	KID	KILL
	KIN	KING	KIT

49.	BEAT	FEAT	HEAT
	MEAT	NEAT	SEAT

50.	BUN	FUN	GUN
	NUN	RUN	SUN

MODIFIED RHYME TEST

TALKER'S LIST

6 PRACTICE FORMS

"Number_____ is_____."

	1	2	3	4	5	6
1	PAD	PAN	PASS	PAT	PATH	PACK
2	HANG	RANG	SANG	BANG	FANG	GANG
3	HIT	KIT	SIT	WIT	BIT	FIT
4	PUFF	PUN	PUP	PUS	PUB	PUCK
5	HOT	LOT	NOT	POT	TOT	GOT
6	DUNG	DUB	DUCK	DUD	DUG	DUN
7	FIB	FIG	FILL	FIN	FIT	FIZZ
8	LANE	LATE	LAY	LACE	LAKE	LAME
9	MALE	PALE	SALE	TALE	BALE	GALE
10	SEETHE	SEED	SEEK	SEEM	SEEN	SEEP
11	DIN	FIN	PIN	SIN	TIN	WIN
12	RAKE	RATE	RAVE	RATE	RAZE	RACE
13	WENT	BENT	DENT	RENT	SENT	TENT
14	SILL	SIN	SING	SIP	SIT	SICK
15	NAME	SAME	TAME	CAME	FAME	GAME
16	DIP	DID	DIG	DILL	DIM	DIN
17	RIP	SIP	TIP	DIP	HIP	LIP
18	PEAK	PEAL	PEAS	PEAT	PEACE	PEACH
19	RAW	SAW	THAW	JAW	LAW	PAW
20	DUST	GUST	JUST	MUST	RUST	BUST
21	BEAD	BEAK	BEAM	BEAN	BEAT	BEACH
22	HOOK	LOOK	SHOOK	TOOK	BOOK	COOK
23	MASS	MAT	MATH	MAD	MAN	MAP
24	BEST	NEST	REST	TEST	VEST	WEST
25	MOP	POP	SHOP	TOP	COP	HOP

MODIFIED RHYME TEST

TALKER'S LIST

6 PRACTICE FORMS

"Number_____ is_____."

	1	2	3	4	5	6
26	PICK	PIG	PILL	PIN	PIP	PIT
27	OIL	SOIL	TOIL	BOIL	COIL	FOIL
28	BUS	BUT	BUCK	BUFF	BUG	BUN
29	SUD	SUM	SUN	SUNG	SUP	SUB
30	TAM	TAN	TANG	TAP	TAB	TACK
31	TEAM	TEAR	TEASE	TEACH	TEAK	TEAL
32	FILL	HILL	KILL	TILL	WILL	BILL
33	LED	RED	SHED	WED	BED	FED
34	COLD	FOLD	GOLD	HOLD	SOLD	TOLD
35	SAKE	SALE	SAME	SANE	SAVE	SAFE
36	PALE	PANE	PAVE	PAY	PACE	PAGE
37	REEL	EEL	FEEL	HEEL	KEEL	PEEL
38	PIG	RIG	WIG	BIG	DIG	FIG
39	HEAVE	HEAL	HEAP	HEAR	HEAT	HEATH
40	CAKE	CAME	CANE	CAPE	CASE	CAVE
41	SICK	TICK	WICK	KICK	LICK	PICK
42	BATH	BACK	BAD	BAN	BASS	BAT
43	CUB	CUD	CUFF	CUT	CUSS	CUT
44	MARK	PARK	BARK	DARK	HARK	LARK
45	HEN	MEN	PEN	TEN	THEN	DEN
46	WAY	DAY	GAY	MAY	PAY	SAY
47	SACK	SAD	SAG	SAP	SASS	SAT
48	KICK	KID	KILL	KIN	KING	KIT
49	MEAT	NEAT	SEAT	BEAT	FEAT	HEAT
50	NUN	RUN	SUN	BUN	FUN	GUN

MODIFIED RHYME TEST

TALKER'S LIST

FORM 1

"Number_____ is_____."

1.	PASS	26.	PIN
2.	SANG	27.	TOIL
3.	KIT	28.	BUT
4.	PUCK	29.	SUN
5.	NOT	30.	TACK
6.	DUG	31.	TEASE
7.	FILL	32.	BILL
8.	LAME	33.	WED
9.	BALE	34.	HOLD
10.	SEEP	35.	SAFE
11.	SIN	36.	PALE
12.	RACE	37.	REEL
13.	DENT	38.	BIG
14.	SIT	39.	HEAP
15.	GAME	40.	CAPE
16.	DIM	41.	SICK
17.	HIP	42.	BAN
18.	PEAS	43.	CUT
19.	LAW	44.	BARK
20.	JUST	45.	THEN
21.	BEAK	46.	SAY
22.	TOOK	47.	SACK
23.	MAD	48.	KING
24.	VEST	49.	MEAT
25.	TOP	50.	SUN

MODIFIED RHYME TEST

TALKER'S LIST

FORM 2

"Number_____ is_____."

1.	PAD	26.	PILL
2.	BANG	27.	OIL
3.	FIT	28.	BUN
4.	PUFF	29.	SUM
5.	GOT	30.	TAM
6.	DUCK	31.	TEAK
7.	FIT	32.	TILL
8.	LACE	33.	SHED
9.	SALE	34.	TOLD
10.	SEEN	35.	SAKE
11.	DIN	36.	PACE
12.	RACE	37.	FEEL
13.	WENT	38.	FIG
14.	SIN	39.	HEAT
15.	GAME	40.	CAVE
16.	DIP	41.	LICK
17.	SIP	42.	BACK
18.	PEACH	43.	CUFF
19.	JAW	44.	BARK
20.	DUST	45.	PEN
21.	BEAN	46.	SAY
22.	COOK	47.	SAP
23.	MATH	48.	KICK
24.	TEST	49.	SEAT
25.	TOP	50.	RUN

MODIFIED RHYME TEST

TALKER'S LIST

FORM 3

"Number_____ is_____."

1.	PASS	26.	PIT
2.	FANG	27.	SOIL
3.	KIT	28.	BUG
4.	PUB	29.	SUB
5.	TOT	30.	TAN
6.	DUG	31.	TEACH
7.	FIB	32.	KILL
8.	LAY	33.	RED
9.	TALE	34.	FOLD
10.	SEEM	35.	SAKE
11.	TIN	36.	PAGE
12.	RAZE	37.	PEEL
13.	BENT	38.	DIG
14.	SIP	39.	HEAP
15.	NAME	40.	CAKE
16.	DIN	41.	TICK
17.	HIP	42.	BAD
18.	PEAK	43.	CUP
19.	THAW	44.	DARK
20.	GUST	45.	PEN
21.	BEAN	46.	WAY
22.	BOOK	47.	SAT
23.	MAN	48.	KING
24.	WEST	49.	MEAT
25.	POP	50.	GUN

MODIFIED RHYME TEST

TALKER'S LIST

FORM 4

"Number_____ is_____."

1.	PACK	26.	PIP
2.	SANG	27.	SOIL
3.	FIT	28.	BUCK
4.	PUFF	29.	SUD
5.	NOT	30.	TAM
6.	DUD	31.	TEACH
7.	FIT	32.	KILL
8.	LANE	33.	BED
9.	BALE	34.	FOLD
10.	SEEK	35.	SAVE
11.	DIN	36.	PAY
12.	RAVE	37.	FEEL
13.	RENT	38.	FIG
14.	SING	39.	HEAT
15.	TAME	40.	CAPE
16.	DIM	41.	KICK
17.	DIP	42.	BAN
18.	PEAS	43.	CUSS
19.	JAW	44.	HARK
20.	BUST	45.	DEN
21.	BEAD	46.	DAY
22.	COOK	47.	SAG
23.	MAD	48.	KILL
24.	BEST	49.	HEAT
25.	COP	50.	NUN

MODIFIED RHYME TEST

TALKER'S LIST

FORM 5

"Number_____ is_____."

1.	PATH	26.	PICK
2.	RANG	27.	BOIL
3.	BIT	28.	BUFF
4.	PUS	29.	SUB
5.	POT	30.	TAB
6.	DUB	31.	TEAR
7.	FIN	32.	TILL
8.	LACE	33.	WED
9.	PALE	34.	SOLD
10.	SEETHE	35.	SANE
11.	TIN	36.	PAVE
12.	RAY	37.	KEEL
13.	RENT	38.	PIG
14.	SICK	39.	HEAL
15.	TAME	40.	CANE
16.	DID	41.	LICK
17.	DIP	42.	BATH
18.	PEAT	43.	CUB
19.	LAW	44.	LARK
20.	BUST	45.	HEN
21.	BEAT	46.	PAY
22.	TOOK	47.	SAP
23.	MATH	48.	KID
24.	WEST	49.	HEAT
25.	POP	50.	GUN

MODIFIED RHYME TEST

TALKER'S LIST

FORM 6

"Number_____ is_____."

1.	PATH	26.	PIG
2.	FANG	27.	COIL
3.	HIT	28.	BUN
4.	PUB	29.	SUM
5.	POT	30.	TANG
6.	DUD	31.	TEASE
7.	FIZZ	32.	WILL
8.	LAME	33.	LED
9.	GALE	34.	GOLD
10.	SEED	35.	SANE
11.	WIN	36.	PAY
12.	RATE	37.	REEL
13.	BENT	38.	PIG
14.	SICK	39.	HEAL
15.	FAME	40.	CAKE
16.	DILL	41.	WICK
17.	RIP	42.	BAD
18.	PEACE	43.	CUSS
19.	RAW	44.	DARK
20.	DUST	45.	MEN
21.	BEAT	46.	DAY
22.	LOOK	47.	SAG
23.	MASS	48.	KICK
24.	VEST	49.	SEAT
25.	COP	50.	RUN

APPENDIX E

PHOTOGRAPH OF VISUAL PERIMETRY SETUP

Figure E1. Visual Perimetry Setup.

APPENDIX F

QUESTIONNAIRES USED FOR

SUBJECTIVE EVALUATIONS I, II, AND III

EOD STUDY

SUBJECTIVE EVALUATION I
(Gross Mobility)

Subject_____ Session: 1 2 3 4 5 6

Clothing Condition: 1-No Armor 2-Min. Armor EOD SUIT 3 4 5 6

Part A.

Instructions: The following is a list of design characteristics of the garment you have just worn. Using the scale below, indicate with the appropriate number whether or not you think the characteristic needs no improvement, needs a little improvement, or needs much improvement. The long line next to the design characteristic may be used to write in why you think the characteristic needs improvement (for example, "sleeves are too long").

1 needs no improvement — 2 needs little improvement — 3 needs much improvement

1. _____ helmet fit_____
2. _____ helmet weight_____
3. _____ visibility afforded by helmet_____
4. _____ collar fit_____
5. _____ collar flexibility_____
6. _____ visibility afforded by collar_____
7. _____ shoulder fit_____
8. _____ shoulder flexibility_____
9. _____ chest fit_____
10. _____ chest flexibility_____
11. _____ waist fit_____
12. _____ waist flexibility_____
13. _____ sleeve length_____
14. _____ sleeve flexibility_____
15. _____ pant leg length_____
16. _____ pant leg flexibility_____
17. _____ overall suit weight_____
18. _____ overall suit bulk_____

Part B.

Instructions: Rank order the movements you performed today according to how much they were interfered with by the suit you wore. That is, the number "1" will be assigned to the movement most interfered with and the number "5" will be assigned to the movement least interfered with.

_____ head movements

_____ arm movements

_____ leg movements

_____ torso movements

_____ walking movements

EOD STUDY

SUBJECTIVE EVALUATION II
(Psychomotor Performance)

Subject _____ Session: 1 2 3 4 5 6

EOD SUIT

Clothing Condition: 1-No Armor 2-Min. Armor 3 4 5 6

Instructions: For each of the following, indicate your opinion by circling the appropriate number.

1. While wearing the suit today, I found it to be:

-2	-1	0	+1	+2
very heavy	somewhat heavy	neutral	somewhat light	very light

2. While wearing the suit today, I felt:

-2	-1	0	+1	+2
very hot	somewhat hot	neutral	somewhat cool	very cool

3. While wearing the suit today, I found it to be:

-2	-1	0	+1	+2
very stiff	somewhat stiff	neutral	somewhat flexible	very flexible

4. While wearing the suit today, I found it to be:

-2	-1	0	+1	+2
very poorly ventilated	somewhat poorly ventilated	neutral	somewhat well vent-ilated	very well ventilated

5. While wearing the suit today, I found it to be:

-2	-1	0	+1	+2
very tight	somewhat tight	neutral	somewhat loose	very loose

6. While wearing the suit today, I found my ability to breathe to be:

-2	-1	0	+1	+2
very difficult	somewhat difficult	neutral	somewhat easy	very easy

7. While wearing the suit today, I found the faceshield to be:

-2	-1	0	+1	+2
very fogged	somewhat fogged	neutral	somewhat clear	very clear

8. After wearing the suit today, I found that it left me:

-2	-1	0	+1	+2
very tired	somewhat tired	neutral	somewhat energetic	very energetic

9. Overall, I found the suit to be:

-2	-1	0	+1	+2
very uncomfort-able	somewhat uncomfort-able	neutral	somewhat comfortable	very comfort-able

10. The best characteristic of this suit is:

_____

11. The worst characteristic of this suit is:

_____

12. In general, my attitude toward this suit is:

-2	-1	0	+1	+2
dislike very much	dislike somewhat	neutral	like somewhat	like very much

EOD STUDY

SUBJECTIVE EVALUATION III
(Preference)

Subject_____

Instructions: You are now familiar with all the bomb disposal suits. If you were assigned to a bomb disposal unit, put a "1" beside the suit you would choose to use in a real life bomb disposal situation. Then put a "2" beside the next suit you would choose. Continue until you have rated all the suits. The number "6" should be placed next to the suit you would least like to use in a real life situation.

_____ fatigues (no armor)

_____ infantry armor

_____ brown suit with short coat

_____ brown suit with long coat

_____ blue suit without collar

_____ blue suit with collar

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